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THE BRITISH JOURNAL OF METALS


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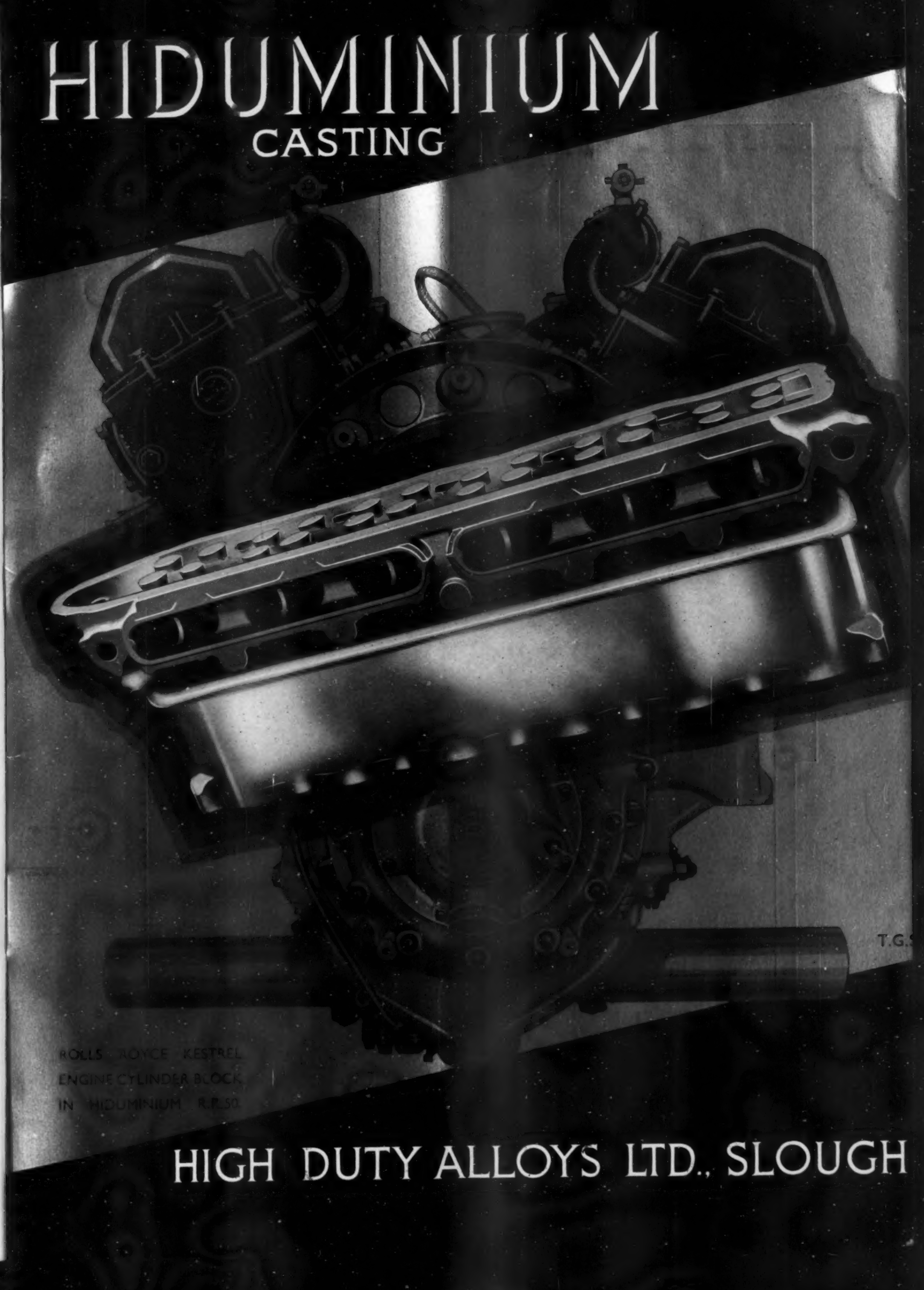
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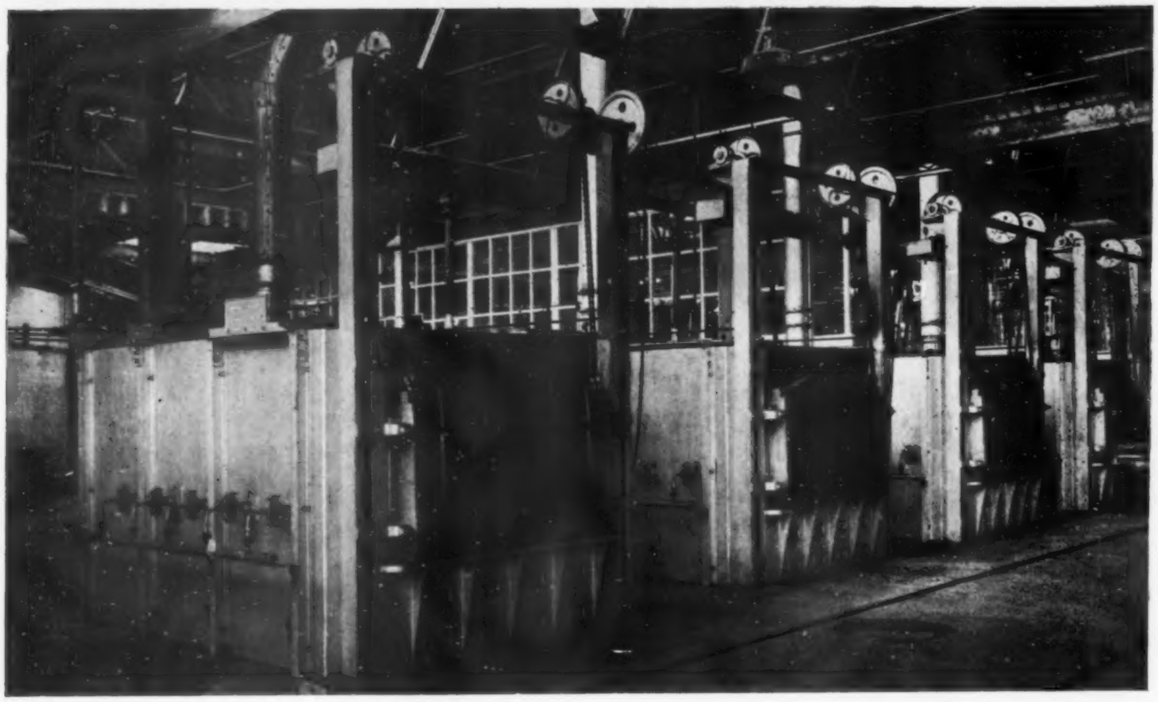

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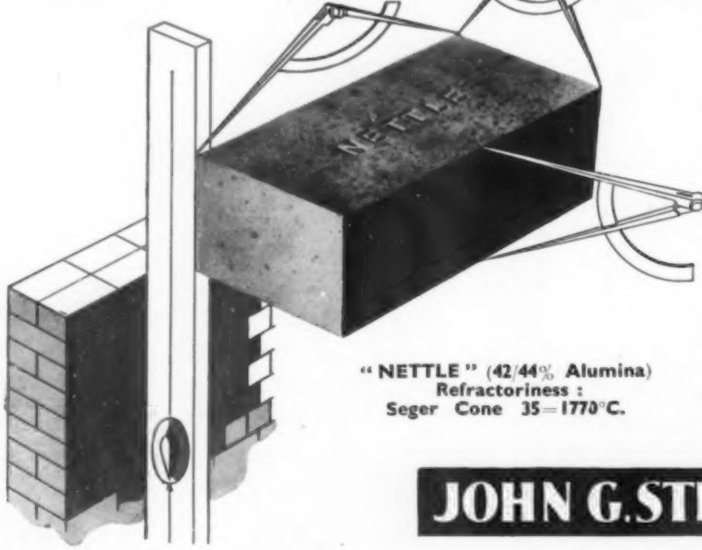
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METALLURGIA

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JULY, 1937. VOL. XVII. No. 93.

Dorman Long's Developments

New Coke Ovens at the Cleveland Works

A new by-product coking plant installed at the Cleveland Works of Messrs. Dorman, Long and Co., Ltd., is described. The plant comprises 136 Simon-Carves "Underjet" compound coke ovens of the Otto Twin-Flue type, having a throughput of 3,000 tons of coal per day; complete by-product plant; coal-handling plant, and coke-screening and handling plant.

DEVELOPMENT in the economical production of iron and steel is indicated by the recent installation of the largest single coke-oven plant ever built in this country, at the Cleveland Works of Messrs. Dorman Long and Co., Ltd. It has been laid down for the production of six to seven hundred thousand tons of blast-furnace coke per annum, and occupies 6¼ acres of ground space. Worked at full output, it will consume over one million tons of coal each year, and, in addition to the coke, will produce 56,000 tons of tar, 3½ million gallons of benzole, and 12,000 tons of ammonium sulphate for fertilisers, while the amount of coal gas liberated for industrial use may be anything from 22 to 34 million cubic feet per day. The cost of the plant is in the neighbourhood of £650,000, and the contract for the work was placed with Simon-Carves, Ltd., who designed and built the complete installation.

The new plant is located at the southern end of the works, the coke-ovens being arranged approximately north and south. The space available for a plant of this capacity was restricted, and in view of the nature of the ground piled foundations were necessary. Apart from the coal unloading, blending, and crushing plant, the whole of the new plant has been located on an area about 600 yds. in length, with a maximum width of 70 yds.

Coal-handling Plant

A number of coals of different qualities are carbonised at the plant, and as careful blending is necessary to obtain the optimum quality of coke, various sidings are laid down so that the different coals can be allocated and discharged in sequence. These sidings lead to an underground hopper into which the wagons are discharged. This hopper is of 50 tons capacity and of sufficient length to accommodate two wagons, which can be unloaded simultaneously. The coal requirements of the ovens are approximately 21,000 tons per week, and can be dealt with by the coal-handling plant working 16 hours per day, 5 days per week.

Blending Bunkers

Coal is fed to the blending bunkers by means of two travelling shuttle belt conveyers. There are ten bunkers for coal and two for breeze. Each coal bunker has a capacity for 200 tons, and each breeze bunker a capacity for 150 tons. Different qualities of coal can be stored separately, and special travelling feeders below the bunkers permit of different types of coal or breeze being discharged at predetermined rates and mixed on to a central collecting conveyer.

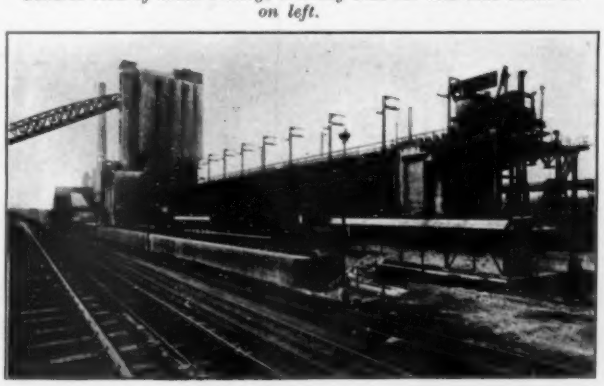
The belt feeders below the bunker mouthpieces are driven by independent motors and variable-speed gears, so that the rate of feed can be regulated as required for mixing purposes. These feeders deliver to a 42-in. troughed conveyer belt running the full length of the blending bunker floor. This conveyer, in turn, delivers to an inclined 36-in. troughed conveyer feeding the coal pulverisers. The pulverisers are of the "Jeffrey-Diamond" hammer type, each having a capacity of 125 tons per hour. Three have been installed, one of which may be isolated to act as a standby.

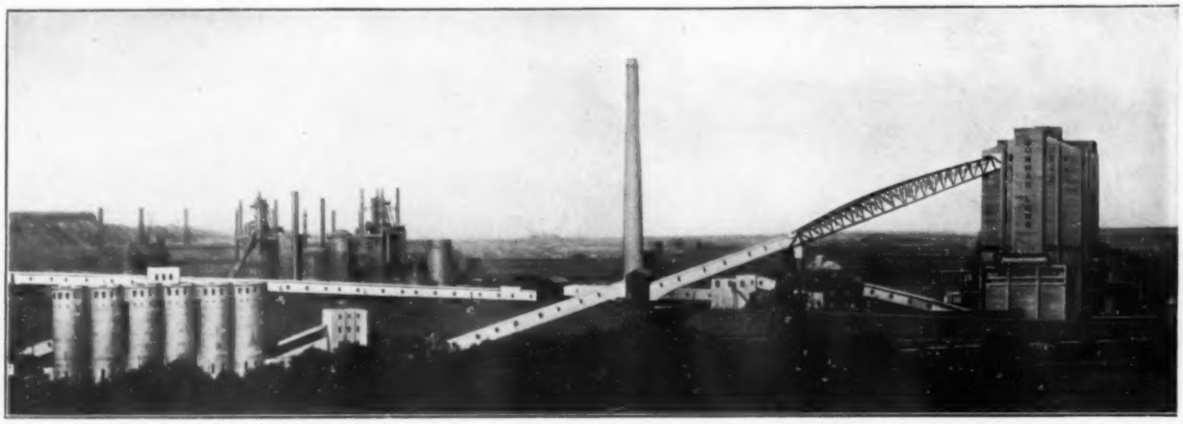
General view of the two batteries of coke ovens from the ram side, showing one of the rams and the service bunker.

On the floor above the coal pulverisers are installed two "Jeffrey-Diamond" breeze grinders, provided with jigging deliveries to the coal crushers below for providing an admixture of breeze to the coal mixture. These breeze grinders are fed from the two special blending bunkers, already referred to, by means of a by-pass arrangement below the bunkers, and delivering on to a special 12-in. troughed conveyer. The crushed coal and breeze is fed through chutes to a short 36-in. troughed conveyer, which feeds a similar conveyer running at right-angles below.

The crushed coal and breeze is delivered on the top floor of the service bunker to a revolving conveyer, which,

General view of south battery, showing coke car and coke bench on on left.





Panoramic view of the complete installation from the coal-handling

in turn, feeds the service bunker evenly and to its maximum capacity. The revolving conveyer is provided with ploughs so that the coal can be discharged at any point along its length to provide even distribution of coal over the whole area of the service bunker. The revolving conveyer is supported on a central pivot carried on concrete beams which form part of the service bunker, and travels on a circular rail track at the delivery ends. The service bunker has a total capacity of 4,500 tons in one compartment.

The motors driving the various conveyers are controlled in sequence, so that a stoppage of any conveyer stops all the conveyers behind it; also, when the plant is put into operation the conveyers start up in their correct sequence. The starting-up is by means of push buttons arranged in convenient positions. Emergency stop buttons are provided where necessary. The switchgear is arranged so that any motor may be cut out of the sequence temporarily for testing or adjustments.

The breeze grinders and pulverisers are not in sequence control for starting, owing to the length of time required to attain their full speed. These machines, however, automatically stop in case of failure of any of the conveyer motors, and should their own motor fail, the preceding portions of the plant are stopped so as to ensure that no spillage of material occurs, and that at no time would breeze be sent to the service bunker without coal.

The Coke Ovens

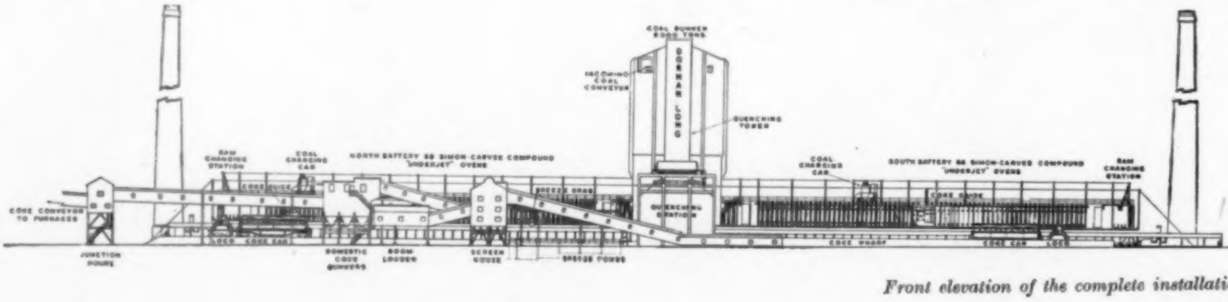
The coking plant is designed for the production of 13,000 tons of furnace coke per week, which involves the carbonisation of 3,000 tons of coal per 24 hours. There are 136 coke-ovens, built in two batteries of 68 ovens each, one on either side of the coal service bunker. Each battery is sub-divided by an intermediate buttress wall into two independent blocks of 34 ovens, forming four separate units, each of which is separately regulatable, thus giving considerable elasticity of coke output.

As the total amount of coal gas evolved during the carbonisation of 3,000 tons of coal per day is in the neighbourhood of 33 million cub. ft., the whole of this quantity is available for industrial use when all the ovens are heated with blast-furnace gas, which requires the consumption of about 55 million cub. ft. of the latter. When the ovens are all heated by coal gas, about 62% of the total gas—say, 20 million cub. ft.—is available as surplus.

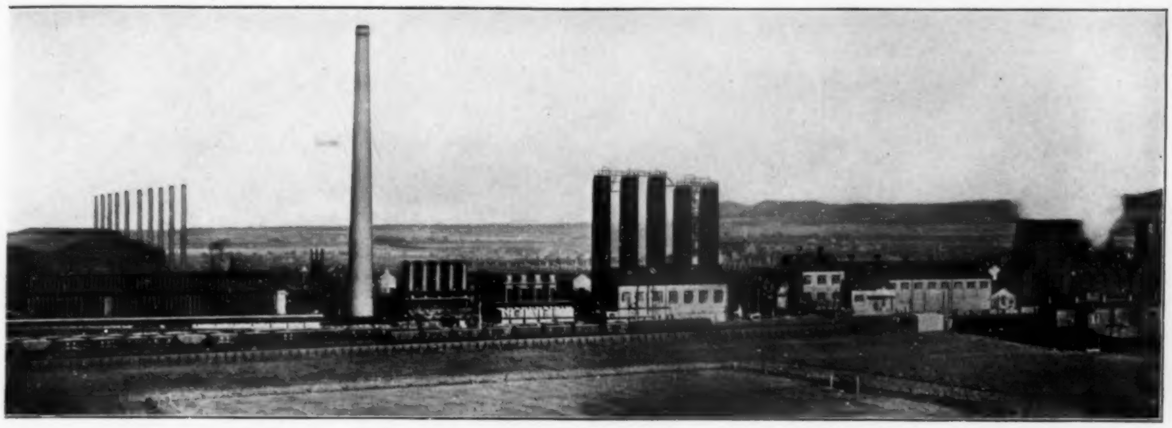
The essential features of the "Underjet" system are: (*a*) The external distribution of rich fuel gas, which enables the quantity of gas burnt in each heating flue to be accurately controlled; and (*b*) the uniformity of pressure along the whole of the heating walls, due to the absence of unbalanced bus flues, which ensures adequate distribution of air and/or lean fuel gas to the various heating flues, without the complication of internal regulating devices. Consequently, the heating of the oven is extremely uniform, and the charge is evenly coked. The only regulating points are adjustments of the fuel gas pressure and the chimney draught.

As the designation "Underjet" implies, the gas mains, burners, and jets are located below the oven structure in a spacious basement formed by the reinforced concrete columns, beams, and decking which support the oven brickwork. Along the sides of the basement run the chimney flues and gas mains carrying the supplies of rich and lean fuel gas. The lean gas mains are connected at each oven to the triplex reversing valve referred to above. The rich gas mains supply lateral pipes the full length of the oven heating wall, with a vertical burner pipe to each heating flue. In the burner pipes are fixed malleable iron jets which are drilled out as required for calibration to $\frac{1}{10}$ mm. to compensate for the variation in thickness of the coal charge, due to the taper of the oven. With this arrangement, an appreciable supply pressure can be used which, maintained constant by a governor, ensures a definite volume of gas passing to each burner as determined by the calibration of its jet.

The oven chambers at Cleveland are 44 ft. 9 in. long, 14 ft. 9 in. high, and $17\frac{3}{4}$ in. mean width, and at the rated coking time of 18 hours nett the throughput per oven is 24 tons of coal per day. The whole of the refractory brickwork is built in moulded shapes, fireclay and semi-silica materials being used in the lower parts of the regenerator



Front elevation of the complete installation



plant on the left to the by-product plant on the right.

walls, and silica shapes in the upper parts of regenerator walls, sole brickwork, and oven-heating walls.

The basement floor under the central service bunker is utilised as a control room which houses the two regenerator reversing winches, rich and lean gas governors, the batteries of control instruments and fuel gas meters. The reversing winches are driven by electric motors controlled by time switches, with standby push-button and manual operation. Above the control room the space at oven sole level is partitioned off for the main electrical sub-station and workmen's accommodation.

There are two complete sets of oven-operating machines. The pushers were supplied by the Wellman Smith Owen Engineering Corporation, and the coal-charging cars, coke guides and quenching cars were built by the Tees Side Bridge and Engineering Works, Ltd., who also fabricated the structural work of the pushers. The two electric locomotives for coke-quenching car haulage were supplied by Messrs. Hawthorn Leslie, of Newcastle-on-Tyne.

The coke having been pushed out of the ovens into the coke cars, the latter are hauled to a central quenching station, where the quenching water from sprays is supplied from a feed-tank of 10,000 gals. capacity. The quenching water is turned on by a switch in the cabs of the electric locomotives hauling the coke cars. The quenched coke is dumped by the cars on to an inclined cooling wharf 255 ft. long, at the lower edge of which hand-operated gates control the discharge on to the coke conveyers.

Coke-Handling Plant

The coke-conveying and screening plant is arranged to handle the coke off the wharf at a rate up to 150 tons per hour. A 42-in. wide belt conveyer running the full length of the wharf enables the coke to be delivered either direct to wagons or over the screening plant. The screens are eight shaft grizzlies, two in number, mounted on portable chassis frames for easy change-over along a rail track in the screen-house floor. The furnace coke passes over the grizzley to a reversible cross conveyer, by which it may be delivered either to a boom conveyer for wagon transport or to a fifth conveyer leading to the blast-furnaces.

The plant is electrically operated throughout, the units being interlocked in three different sequences, all controlled from the primary screen-house. During the operation of any sequence, all units not required are automatically switched out of commission, and an efficient loud speaker telephone system is installed from each loading station to the primary screen-house, which enables the switching over of the coke to the various points of disposal, to be carried out with a minimum loss of time.

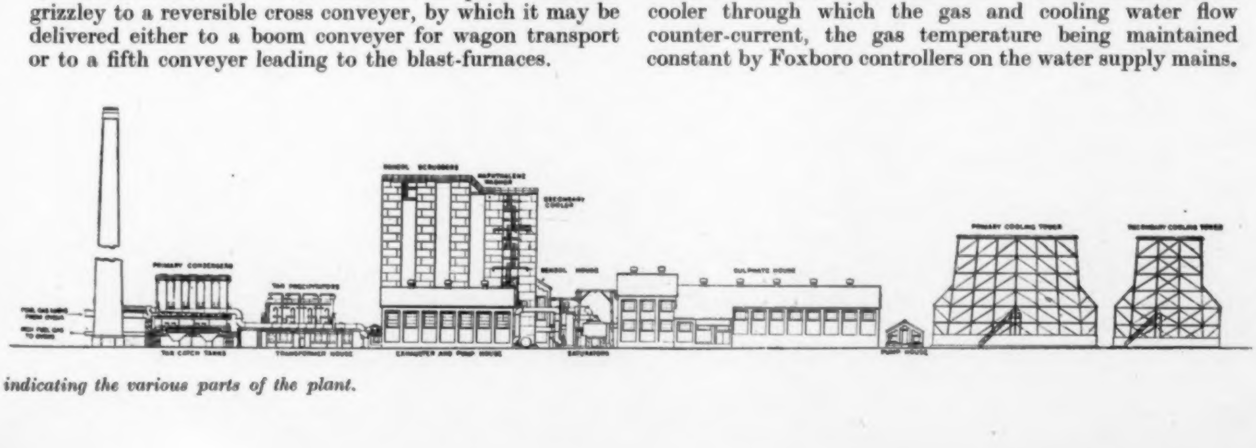
The By-Products Plant

The plant installed for the recovery of the by-products—principally tar, ammonia, benzole, and naphthalene—is arranged on the semi-direct system, which operates as follows. The gas coming from the ovens at 80–90° C. is first cooled in a primary condensing plant to 35–40° C., which results in the deposition of a portion of the tar and some of the ammonia in the form of ammonia liquor. The remainder of the tar, which is now present in the gas in vesicular form, is then completely removed by electrostatic precipitators, leaving the bulk of the ammonia to go forward in gaseous form in the gas stream.

The tar-free gas then passes through the exhauster to the saturator, where the ammonia is removed by combination with sulphuric acid and recovered directly as ammonium sulphate. The ammonia which had separated out as liquor in the condensers is decanted from the tar and distilled, and the resulting ammonia vapour is returned to the gas stream immediately before the saturator. After the saturator the gas is cooled by direct water sprays to 20° C., and finally scrubbed with oil for the extraction of the benzole.

The gas from the ovens arrives in two streams, which combine at the inlet of the primary condensers. There are five condenser units through which the gas passes in parallel, and thereafter the gas is dealt with in a single stream.

Each condenser unit consists of a vertical multi-tubular cooler through which the gas and cooling water flow counter-current, the gas temperature being maintained constant by Foxboro controllers on the water supply mains.



indicating the various parts of the plant.

The oven tops, showing coal-charging car.

The battery of condensers stands on a reinforced concrete entablature, the space underneath being bricked in to form the coking plant laboratories.

There are four Simon-Carves electrostatic detarrers, through which the gas next passes in parallel. The treater chambers consist of steel towers, containing nests of vertical tubes. In the centre of each tube is suspended a wire electrode. A high potential current being applied to the electrode, an intense electrical field is created within the vertical tubes through which the gas passes. The tar fog present in the gas becomes ionised, and the globules are impacted on the walls of the tubes and disintegrated. The tar runs down the tubes and flows away through seal pots.

The gas exhausters are turbine-driven sets of Richardson's Westgarth-Brown Boveri design. Two sets are installed, one being in reserve. Each exhauster is capable of handling 2¼ million cub. ft. of gas per hour, against a pressure difference of 100 in. water gauge at a speed of 4,250 r.p.m. They are two-stage machines, with impellers of stainless steel, and are direct coupled to 800 h.p. single-stage pure impulse turbines of R.W.–B.B. design, operating at 120 lb. steam pressure, and exhausting into a low-pressure steam main at 30 lb. pressure. The exhaust steam is used for process work.

The control of the suction created by the exhausters is effected by varying the speed. Steam is admitted to the turbine through valves operated by oil pressure, and therefore variation in oil pressure affects the admission of steam. In the oil pipe-line a leak-off valve is inserted, and this is controlled by an Askania governor, the diaphragm of which is influenced by the pressure in the gas suction main. Both exhauster sets and the battery of instruments are fixed on an elevated platform of reinforced concrete, under which are the gas and steam mains and valves—the valves being operated by handwheels on the exhauster platform.

The Sulphate Plant

After the exhausters, the gas passes to the sulphate plant for absorption of the ammonia and its recovery as ammonium sulphate. The sulphate plant is in two units, one of which is a standby, and each unit comprises gas-heater, saturator and circulating apparatus, salt-receiving pan and centrifuge. The working temperature of the process is controlled by a multi-tubular gas-heater on the gas stream before the saturator and connected to the low-pressure steam supply.

The saturators are fixed in the open outside the sulphate-house, and a steel runway is provided overhead for removal of ejectors and similar purposes. Inside the sulphate-house is situated the apparatus for dealing with the salt ejected from the saturators and for the control of the process. The centrifuges and salt-handling apparatus are capable of dealing with 2 tons of sulphate per hour.

Final Cooling and Scrubbing of the Gas

The gas, now free from tar and ammonia, leaves the saturators at about 50° C. and is finally cooled by direct water sprays to 20° C. before being scrubbed with oil for the recovery of benzole. According to the Otto system, the cooling and absorption of naphthalene are combined in one process.

There are two final cooling towers; the first is a pre-cooler, where the temperature is brought down to the dewpoint of the naphthalene oils contained in the gas. In the second, the grid packing of the lower half, where the gas enters, is irrigated by partly benzolised preheated oil bled off one of the scrubber circulating pumps. This absorbs the naphthalene, which would otherwise be deposited in solid form, and the naphthalene is subsequently recovered in the benzole plant. The upper portion of this tower is irrigated by direct water sprays to complete the cooling of the gas.

The effluent water from the cooling towers is decanted and led direct to a cooling frame, from which it is re-circulated over the towers. The final temperature of the gas is maintained constant by thermostatic valves in the water mains.

There are three benzole scrubbers, and as the finally benzolised oil is pumped direct from the last scrubber to the benzole stills, any alteration in feed to the stills is automatically adjusted throughout the scrubber circulation system, and this part of the plant practically runs itself. The service and circulating pumps for the scrubbers are all electrically driven, and are installed in the exhauster-house.

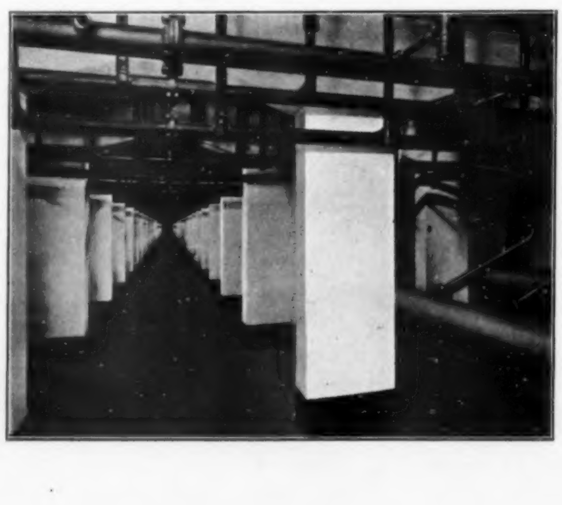
The Benzole Plant

There are two units of apparatus for distilling the benzolised oil from the scrubbers. The two units are capable of producing 12,000 gals. per day of creosote-free benzole equivalent to "one-run" spirit. The recovery averages about 4 gals. of spirit testing 70–75%, at 120° C. per ton of dry coal, with the residual oil-testing to complete denudation at 120° C., and well under 1% at 180° C.

Each distilling unit comprises a still operated by steam preheater, dephlegmating and condensing units, and an oil-cooler formed of banks of pipes in serpentine form, with external water sprays. The oil-cooler pipes are heavily galvanised. The benzolised oil is regulated before a Kent flow-indicating meter, and all temperatures and pressures are controlled by thermostatic valves and regulators, so that the plant works automatically and requires practically no supervision.

A week's storage of benzole is provided in the plant; no rectifying is done at Cleveland, all the spirit being sent to Dorman Long and Co.'s central rectification plant at Port Clarence.

General view in oven basement, showing the "underjet" system of heating the ovens.



Handling the Tar and Ammonia Liquor

The ammonia liquor and tar removed from the gas in the primary condensers, detarrers, catch-tank, etc., are collected in a low level condensate tank from which the mixed condensates are pumped to a storage tank provided with adjustable weir valves, where the liquor and tar are decanted off to flow to their storage tanks of 460 tons and 900 tons capacity respectively.

There are three steam-driven plunger pumps, each of 160 gals. per min., for handling the condensates, for tar-loading and reserve. The ammonia liquor is delivered by one of two 80-gals. per min. motor-driven centrifugal pumps to the ammonia still, and a similar pump handles the still effluent.

All the above pumps along with the spray liquor pumps for the ovens, are installed in the exhauster-house. About 130 tons of tar are produced daily. There are also installed in the exhauster-house two boosters, one of which is electrically driven, and the other steam-driven. These supply gas to Dorman, Long's Redcar Works through a 15-in. pipe-line, which is 3½ miles long.

Test Results

Test results obtained during a run of three weeks under normal conditions are given in the following table, and a comparison between the guarantee figures and those obtained under test are very gratifying.

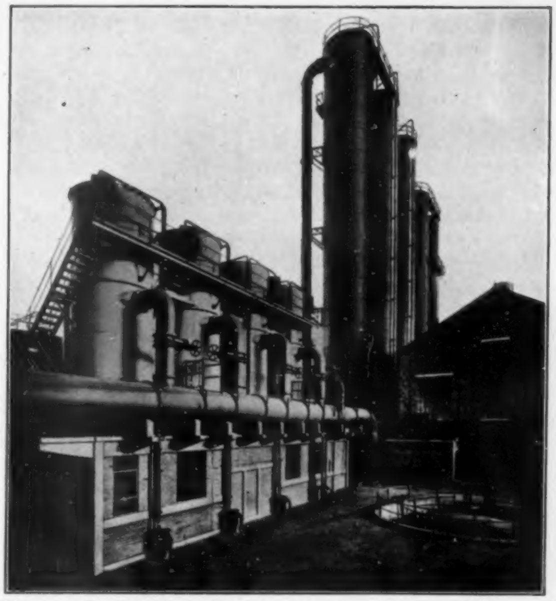
	Guarantee.	Actually Obtained.
Furnace coke over 1½ in. cube per week.	13,000 tons ...	13,586 tons
Recovery of tar from gases	Not less than 99%.	Residual tar in gas immeasurably small.
Ammonia recovery	Not less than 99%.	99·47%
Benzole in stripped gas in grams per cub. m.	Not more than 2 grms.	0·96 grms.
Heat required to carbonise 1 lb. of wet coal containing 8% free moisture based on the nett C.V. of the heating-gas.	Not more than 950 B.th.u.	900 B.th.u.

Water, Steam, and Electricity

The water circulation for primary condensers and benzole plant cooling is effected by two of three electrically driven centrifugal pumps at a maximum rate of 3,500 gals. per min. The effluent hot water from the condensers and coolers flows by gravity over a Brotherhood chimney-type cooling frame of 200,000 gals. per hour capacity, built in separate halves for cleaning purposes, and the cooled water is recirculated by the above pumps. The make-up water to compensate for the evaporation in the cooling frame is obtained from the town's water main.

An entirely separate circulation is maintained for the direct-spray gas coolers. This is effected by one of two centrifugal pumps at the rate of 1,200 gals. per min., and the water is recooled over a second cooling frame of 72,000 gals. per hour capacity.

By-product plant showing primary gas coolers in foreground, and tar and liquor tanks on left.



Electrostatic detarring plant in foreground with scrubbers and coolers behind and exhauster house on right.

River Tees water is used for the oil-coolers at the benzole plant, but a reserve town's water connection is provided for this service also. All the nine water pumps referred to above are located in a pump-house built alongside the cooling frames, and their working is supervised by the benzole-house process man.

A high-pressure steam main, 12 in. diameter, carries the steam from the steelworks ring main at the North end of the site. From this point the main is welded in one continuous length throughout the plant. A low-pressure main collects the exhaust steam and conveys it to the ammonia and benzole stills, gas-heaters, etc., and the supply is maintained by a Foxboro pressure controller, regulated from the exhauster-house instrument panel, which bleeds off from H.P. to L.P. main.

Gas Governors

The first call on the gas is the fuel supply to the ovens, and this is regulated by an Askania governor in the return gas main, and as long as there is only sufficient pressure available to supply the ovens' demand all other governors dealing with surplus gas remain automatically closed. As the pressure in the surplus gas main rises, a diaphragm governor on the supply main to the gas boosters opens, and further pressure rises open in succession similar governors to the steel works' mains and the gas-bleeder. The gas-bleeder is a triplex pipe structure with three governors set at progressive pressures. The supply of blast-furnace gas is controlled by Askania governors. Since the completion of the contract Messrs. Dorman, Long have decided to install a gas-holder, and a 750,000 cub. ft. Klonne-type holder is now being erected.

Instruments

A very full equipment of instruments is provided for the control of the plant. Pressure-indicating and recording is effected by ring-balance strip-chart instruments supplied by the Drayton Instrument Co., while the Cambridge Instrument Co. were responsible for the recording pyrometers and thermometers. All the volume-measuring instruments were made by Geo. Kent, Ltd.

Electrical Distribution and Equipment

There are two electrical sub-stations referred to as "Bunker Sub-station" and "Detarrer Sub-station" respectively. The three-phase 50-period electric supply is

taken either from the grid system or from Messrs. Dorman, Long and Co.'s works' generating plant at 11,000 volts, at which pressure it is brought into the Bunker Sub-station at the coke-oven plant. In this sub-station there are installed two three-phase transformers, each of 2,000 K.V.A. capacity, connected through main circuit breakers, one on each alternative supply, to reduce the voltage to 2,750 volts for distribution to the coke-oven plant, by-products plant, and coal-handling plant. A third transformer is kept ready to be connected up in case of breakdown of either of the two permanently connected units.

All motors of 110 b.h.p. and over are supplied at 2,750 volts, and others at 440 volts. The low-tension motors on the by-product and oven sections are supplied from the two 650 K.V.A. transformers through two distribution switchboards, of ten and eight panels respectively, one panel on each being reserved for the lighting transformers. These two switchboards are coupled together in such a say that, in the event of a breakdown of one of the 650 K.V.A. transformers, essential motors in each section could be supplied from the other in order to avoid complete shut down. All H.T. and L.T. switchboards have a bus-bar voltmeter and an ammeter on every panel.

At the coal-handling plant a high-tension switchboard fed from the main 2,750 volt board in the Bunker Sub-station carries panels for three 200 b.h.p. motors, and one 300 K.V.A. 2,750–440 volt transformer to which a low-tension switchboard of five panels is connected to supply the distribution boards controlling the low-tension motors and the lighting transformer.

Causes of Trouble in Heat-Treatment

Pyrometers and Recorders

IN the larger firms engaged in heat-treatment the checking of the pyrometer system is a normal routine, and is usually performed by individuals who have an adequate knowledge and experience of the instruments under their care. Firms not possessing such internal facilities sometimes compromise by engaging the Instrument Manufacturer to carry out a monthly, three-monthly or half-yearly test.

There are, however, a very large number of heat-treatment departments where no checking is done, and where pyrometers are accepted as inevitably correct or incorrect according to the psychology of the hardener. The writer, in the course of his duties, is in daily contact with all three classes of users, and has become more and more aware of heat-treatment department troubles which can directly be attributed to a general ignorance of the principles of pyrometry.

This is especially the case with the smaller firms who accept the instruments as "gospel," and leave it at that; but even in the second classification, where periodic checks are made by the instrument makers, the tendency is to accept the check test as a clean bill for the next six months, the responsibility having thereby been passed outside the department concerned! For this attitude the pyrometer suppliers cannot escape some indirect responsibility. They no doubt believe that they are manufacturing very delicate instruments, that unskilled adjustment is highly undesirable, and that with pyrometry, as other matters, a little knowledge is dangerous to the users and themselves.

They also appreciate the risks in an over emphasis of troubles which may not arise, by which an operator becomes nervous and a worry to himself and his job. In consequence, therefore, the tendency has been the attempt to make pyrometers more foolproof, and in modern installations this is certainly more evident, but even these installations may get out of order now and again.

There are, however, scores of firms with older instruments where the conditions are entirely unsatisfactory, and where the periodic check test is quite inadequate. The factors concerned in this state of affairs may be tabulated as follows :—

A. An ignorance of the elementary fundamentals of pyrometry.

B. A muddled knowledge of cold junction effect.

C. No appreciation of the implications of internal and external resistance.

D. Neglect of the primary fact that a poker type couple only needs its own temperature.

The writer is in a position to quote numerous examples of A, B, C, D, whereby continuous or fluctuating trouble has resulted, especially B—the cold junction effect. This can be of grave importance in the heat-treatment of light alloys where there is little tolerance in the temperature limits of the solution and precipitation treatments.

Happily the results are so obvious that the trouble is not prolonged. With steels, however, an error of 20° C to 30° C may pass unnoticed, whilst more serious discrepancies are usually remedied by an arbitrary Zero setting, so that the instrument is in agreement with the hardener's belief in his own judgment.

It may be the opinion of the makers of instruments that this state of affairs will be cured by the more foolproof nature of the modern and the gradual elimination of the older installations, and they doubtless appreciate the difficulties in the path of the education of the untrained user.

The fee charged for periodic checking may not allow the time necessary for an investigation of the temperature of the job as distinct from that of the couple, and they may with justice suggest that this is a matter for the furnace people. The function of a temperature-recording instrument is, however, that of correctly recording the temperature of the job, as the function of a micrometer is to give the dimensions of a component; most firms go to some trouble with their micrometers and gauges and they would certainly refuse to accept a faulty gauge as an adequate excuse for wrong dimensions. It is, therefore, seriously suggested that executives should adopt a more realistic attitude to their temperature indicators and recorders and that they should demand from their hardener or chemist, not only the fundamentals of their immediate job, but a sufficient knowledge of the instruments they use in the performance of that job.

With this demand for a higher standard of efficiency, the instrument suppliers should have every sympathy, and they could then, with more enthusiasm, help the process of education among users to a greater degree than they feel at present justified or desirable. From the writer's experience of such suppliers they will courteously give every possible assistance when requested.

What is regrettable is the large numbers of heat-treatment departments where the pyrometer equipment is not only out of date, but a serious source of fluctuating error, and even more regrettable where this error is an ever present excuse in time of trouble, and the inevitability of it accepted by all concerned. An excuse and inevitability which would not be tolerated for a minute in a department responsible for dimensions and dimensions only.

H. T.

[The Editor welcomes contributions under the head "Causes of Trouble in Heat-Treatment." Such contributions, for which payment will be made, should be reasonably short and to the point.]

METALLURGIA
THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

Research and Industrial Progress

The Work of the National Physical Laboratory

RESEARCH is the systematic exploration of the unknown. Discovery and invention do not often spring full grown from the brains of men but are the practical results of long and arduous research. The rare occasions when discoveries were made by happy accident belong largely to the past, to those times when there was little or no prior knowledge upon which to base experiments or ideas, but the inspiration or accident then formed the basis for continuous development, much of which work consists of ascertaining and labelling the avenues investigated, so that further investigation will not lead to confusion.

The labour of a host of men, of great laboratories and long patient research, build up the sound structure of knowledge and contribute to progress. Sometimes the building proceeds brick by brick, but often progress appears slow, until the addition of fact to fact culminates in a revolutionary discovery. Systematic exploration avoids confusion, reduces the possibility of premature conclusions, indicates the often unexpected influence of one factor upon another, and results in the final application of a discovery or development for the greatest benefit of mankind. It is this research which is the essential basis of industrial progress.

The majority of industries and large works run their own laboratories and, although many of these deal with work of a routine character, much research work is done in specialised fields. The work of the National Physical Laboratory covers many fields of exploration and as a central organisation, the value of the work accomplished is more apparent by comparison with the localised research of these many industrial laboratories.

At the National Physical Laboratory the work is distributed in eight technical departments, physics, electricity, radio, metrology, engineering, metallurgy, aero-dynamics and the national tank. It covers a very wide field and much of the work done and in progress proved both interesting and informative on the occasion of the recent inspection by the General Board.

It is not possible here to describe all the work of this Laboratory, but some indication can be given by reference to some of the work done or in progress. Thus in problems which arise in the manufacture of steel, including the processes of annealing and normalising, the heat evolutions at the transformation points are of importance. These are now being studied at the Laboratory by adiabatic calorimetry carried out at the temperature of the transformation itself. A heater is inserted within the ingot, whilst a jacket surrounding it is heated by a circuit which can be separately controlled. The whole apparatus is in a vacuum. Thus, when the heater within the ingot is in operation, if the jacket is maintained always at the temperature of the ingot, heat loss from the latter is suppressed. The energy input to the heater is then equal to the product of the temperature rise of the ingot and its specific heat (when there is no transformation in the range considered), or to the heat of transformation (when the experiments are carried out in the temperature range where this occurs).

Corrosion fatigue tests have been engaging the attention of the Laboratory for some time. The results of these tests are very illuminating and represent a valuable addition to our knowledge of the behaviour of various metals and alloys subjected to corrosive attack; they have thrown much light on the causes of many failures which were previously unexplainable. The researches have shown, for instance, that the fatigue resistance of some metals is considerably reduced even by contact with the atmosphere; thus, comparing the resistance in air with that in a vacuum, lead has half the resistance, brass about 80 per cent., copper about 90 per cent., and mild steel about 95 per cent., while specimens of cupro-nickel and magnesium alloy show no change. The research also showed that the active agent causing this effect was oxygen in the presence of water vapour. When tests are carried out using a salt spray as the corrosive agent, it is found that the reduction in resistance of steels other than stainless steels is very great; a steel capable of withstanding an alternating tension and compression of 25 tons per sq. in. was found to have its resistance reduced to about one-tenth of this value under the salt spray conditions.

An investigation has also been made into the possibilities of using protective coatings on steels which are normally subject to this corrosive attack; some of these coatings have given almost complete protection. Certainly the information obtained from the research provides much useful data for the designer.

The introduction during recent years of cast crankshafts marks a development in automobile and general engineering of considerable importance. Five cast materials, already in production for this purpose, have been investigated. The main object was to determine the behaviour of the materials under conditions of combined bending and torsional fatigue stresses. A factor of considerable importance emerging from the results is the high resistance to fatigue of the materials when related to their tensile strength.

Alloys of Iron and Carbon

The alloys of iron with carbon form the basis of nearly all steels, it is therefore important to know the melting, freezing and transformation temperatures of the pure alloys. Since the measurements of Carpenter and Keeling, carried out at the Laboratory and published in 1904, it has been found possible to prepare iron of higher purity, whilst a further transformation, not then known, has been discovered. A revision of this alloy system was found to be desirable and has now been completed so far as the behaviour of alloys containing up to one per cent. of carbon is concerned, with the purest available materials and with modern precautions to avoid contamination.

Several laboratories are collaborating in the work of establishing oxygen in commercial steels, and various methods are being examined. The Laboratory has been studying this oxygen question for some time, and has devised special apparatus for the purpose. The total oxygen is determined by melting the steel in a graphite crucible and analysing the gases given off. It is also necessary to know how much of this oxygen is combined with other elements in the non-metallic inclusions in the steel. For this purpose samples are dissolved in a solution of iodine, air and substances containing oxygen being excluded, and the insoluble residue amounting only to a few milligrammes, is analysed by microchemical methods.

Dental Alloys

Another investigation of considerable interest is that which has been carried on over several years on dental alloys. The main results of this work show the relation between the composition of the dental alloy and the volume change of the amalgam during setting, the changes of volume being observed over several days. The most satisfactory results have been obtained from silver alloys containing not less than 25 per cent. and not more than 27 per cent. of tin, the variation between these limits depending on the copper content of the alloy. The limits within which an amalgam will neither contract nor give an excessive expansion are therefore very narrow.

Magnesium Alloys

Considerable work has been carried out on aluminium and aluminium alloys and present progress in this section of non-ferrous metallurgy is due in a large measure to the results obtained from this work. Work of a somewhat similar character is now in progress with magnesium alloys, which has resulted in the development of an alloy possessing relatively high strength. In addition to research on suitable compositions efforts are constantly being made to increase the strength of these alloys by improving the methods of forging and a heated press, which operates under controlled conditions, has been developed. The method has been found to effect a considerable increase in the strength of the alloys.

Testing Machines

The development of testing machines is an important function of the Laboratory and mention may be made of an experimental wear testing machine for gauge steels which has been designed and constructed It comprises a lapping device by means of which the comparative resistance to wear of different gauge steels is determined from the loss in weight sustained by similarly shaped specimens of the steels when subjected simultaneously to the action of the lap for a given time. The specimens are in the form of rings which rest with one of their annular faces in contact with a circular, horizontal lapping table. Each ring is made to rotate about its own axis by means of a spindle (of which there are three) and at the same time the lapping table itself is slowly turned.

An appliance has been designed which is capable of detecting errors as small as 0·00005 in. in the truth of the helix of the threads of plug screw gauges. Another development of value to the engineer is the horizontal projection machine for large objects. By the employment of suitable lenses, plate gauges up to 3 ins. in length can be projected as a whole to a magnification of 25 while the threads of screw gauges up to 8 ins. in diameter and the teeth of large gear-cutting hobs can be examined at a magnification of 50.

Both in pure science and in its application to the arts, research is one of the most potent impulses to progress, because it is organised research that gives improvement in materials, machines, processes, and in understanding. In this work the National Physical Laboratory is contributing in no small degree and it is noteworthy that it is always ready to give careful consideration to any problems which may be submitted to it and to undertake experiments when it is thought that with the facilities at its disposal a solution may be found.

Market Your Scrap Iron and Steel

An Appeal to All Who Have Scrap Iron

THE illogical position that this country should export scrap iron and steel whilst importing scrap at scarcity prices was brought to an end by the recent agreement with the National Federation of Scrap Iron and Steel Merchants.

Prominence has been given to the requirements of the nation for scrap, and an appeal made to the public, as well as to all industries, to avoid the wastage of this useful commodity, the campaign being scheduled to continue until the end of this year and directed by the British Iron and Steel Federation.

There is no doubt, and this is confirmed by our own observations, that a considerable quantity of scrap metal and old plant are regularly sold by many industries, but there is also considerable accumulation that could be marketed. This is a matter of national interest as well as a source of revenue to the various holders of that accumulation.

Naturally, members of many trades and industries will be particularly interested in supporting this campaign, knowing that scrap is a raw material contributing to steel manufacture in the proportion of over 50% of ingot output. For instance, in 1936 6,700,000 tons of iron and steel scrap were used in the manufacture of 11,800,000 tons of steel, and of this quantity 3,100,000 tons were collected from domestic sources, and 1,100,000 tons were imported.

Scrap proportion used varies with geographical conditions. In the Lincolnshire steelworks the percentage of scrap was as low as 26%, but the Scottish steel furnaces consumed 79% of scrap in 1935. The South Wales steel makers used 76% scrap in the 1935 production.

Additional figures will serve to emphasise the significance of the present movement. In 1936 35½ tons of scrap were used for every 100 tons of steel, in the first quarter of 1937 this proportion rose to 38% ; a monthly average of 90,000 tons of iron and steel scrap were imported in 1936, but the monthly importation fell to 42,000 tons for the first five months of this year. Last year the melting of approximately 4,250,000 tons of scrap produced by steelmakers at home and abroad resulted in the economy of some 14,000,000 tons of domestic iron ore and 6,000,000 tons of British coal.

Support can be given to this campaign by instructing assistant managers, foremen, etc., to collect broken tools, redundant parts, manufacturing waste and similar rejects in one place in every works, in addition to the usual circulating scrap metal accumulation and disposal.

We understand that the scrap metal market is fully organised for the collection and sorting of all kinds of scrap, and that prices are regulated for each different grade.

Occurence of Nickeliferous Pyrrhotite in Nova Scotia

THE occurrence of a nickel-bearing rock in the vicinity of Middle River, Cape Breton Island, Nova Scotia is reported by Professor G. V. Douglas and R. L. Milner of Dalhousie University. The discovery is unique in the history of mining in Novia Scotia, being the first occurrence of nickel ever reported in the province although low grade nickel deposits have been found in New Brunswick. Carefully checked analyses showed 1·16 per cent. nickel. Although the nickel minerals were found in Precambrian rocks no basic igneous rocks such as occur with other nickel deposits throughout the world are known in the area.

Ontario is the world's greatest producer of nickel but commercial deposits are also known in British Columbia, Norway, and New Caledonia.

The Melting of Grey Cast Iron in Different Types of Furnaces

By S. E. DAWSON.

Various factors which influence the character and properties of cast iron are briefly discussed, with particular reference to the method of melting employed; a comparison made of various types of melting furnaces in use; and some indication given of the approximate relative cost of melting. Attention is directed more particularly to the cupola and to rotary melting furnaces.

IT has long been recognised that the method of melting cast iron may have considerable influence on some of its fundamental properties. As an inherent part of such processes of melting commonly used in the foundry, there are usually one or more characteristics which may be considered as influencing the resulting product, although it is not altogether clear at present how these may be correlated. Such factors include, in addition to the type of raw material employed, the temperature attained during melting, the time of operation, the extent of contact with and nature of gases and slag. These are to some extent inter-dependent on each other—that is, a variation in one will automatically bring about changes in other conditions which may cause modification of the cast iron in respect of structure and physical properties. Where parts of the charge are added, subsequent to the melting of the main bath of metal, as in open-hearth and crucible melting, altered structures may also result.

Recent investigations into cast iron of similar chemical analysis though of different physical properties indicate that the condition of the graphite carbon has a large bearing on such variations. The effect of rate of cooling and composition on the graphite is already well known and follows well-defined laws, but may be further modified by melting conditions. The knowledge gained on this aspect of cast iron in recent years seems to provide a reason in many cases for the so-called "heredity" or persistence of the character of a cast iron after remelting. In this connection the part played by absorbed gases has still to be fully investigated, although the effect of certain non-metallic inclusions on the graphite size has already been shown to be of considerable importance.

Of more immediate practical interest, perhaps, is the persistence after remelting of some of the properties of the raw materials employed in the charge. Hurst showed that by selection of raw materials of known physical properties, predetermined mechanical properties in the final metal can be secured by suitable blending. Boegehold examined cast iron, melted under constant conditions in a cupola, from pig irons produced in several different blast-furnaces. The cupola charges for the remelts included in all cases the selected pig iron and scrap from a previous melt of the same pig iron, and test specimens were taken from the middle of the melt at a pouring temperature of 1,330° to 1,370° C. He found that blast-furnace conditions produced characteristics in the pig iron which persisted through subsequent melting in the cupola, as evidenced by many of the test results from both metals. This was especially observed with regard to hardness and fluidity in relation to composition, and the dilatometer test curves which were of the same form in each pair.

The latter tests also showed in a marked degree the influence of the quality of coke employed and the amount of moisture in air supplied in both the blast furnace and the cupola. The effect of moisture in the blast increased the chill and combined carbon progressively when no similar influence due to composition could be observed.

The effect of the quality of the coke may also be seen from the results obtained by W. E. Jominy, in his comparative tests on irons melted by means of charcoal and coke. In all, about 100 lots of iron were examined, and again the pig iron was remelted under constant conditions to reduce subsequent variables to a minimum. An electric furnace was employed for this purpose, and the analyses showed that little change in composition had occurred.

The iron was remelted at 1,430° C., and, as in the case of the iron from the blast-furnace, poured into test-bars 1¾ in. diameter by 15 in. long. The irons he employed were of considerable and useful range, and the mechanical tests taken included those on the original pig iron as well as on the remelted and twice remelted cast iron. The tensile and transverse strengths in the case of the first remelt and for equal silicons show the charcoal melted irons to be about 20% stronger than the coke-melted irons.

A balanced-blast cupola in operation.

On remelting a second time, this difference had persisted, the actual comparisons in the three stages being shown in the accompanying table.

The micro-structures showed that in the stronger irons the graphite was much smaller and well distributed, whilst that in the weaker irons was large and coarse. In general, the charcoal-melted irons tended towards the former type of graphite.

Norbury and Morgan* suggested that the presence of solid inclusions promotes larger graphite growth, whilst super-coating to form fine graphite occurs if the inclusions are liquid. They have shown that if the irons containing such inclusions, as almost all cast irons do, are subjected to oxidising gases, fine graphite results, whilst with reducing gases coarser forms are precipitated. This is found to take place in the presence of titanium, the oxide of which reduces the melting point of slag, possibly coating the inclusion with a fluid or semi-fluid exterior and so rendering it innocuous as a graphite precipitant.

* Iron and Steel Institute, Sept. 1936

—	Blast-furnace Fuel.	Si	Mn	P.	S.	T.C.	Transverse Strength, Lb.
Pig iron	Charcoal	1·98	0·70	0·133	0·009	4·19	2 700
First reme't		1·90	0·70	—	—	3·90	3,700
Second remelt		1·83	0·67	—	—	3·79	3,500
Pig iron	Charcoal	2·02	0·70	0·137	0·012	4·17	2,600
First remelt		1·91	0·61	0·136	0·013	4·04	3,450
Second remelt		1·87	0·57	0·139	0·015	3·96	3,300
Pig iron	Charcoal	2·20	0·49	0·166	0·009	4·04	2,500
First remelt		2·15	0·48	—	—	3·86	3,200
Second remelt		2·11	0·45	—	—	3·82	3,000
Pig iron	Charcoal	2·69	0·49	0·137	0·009	3·83	Holes
First remelt		2·47	0·49	—	—	3·79	3,500
Second remelt		—	—	—	—	3·67	3,550
Pig iron	Charcoal	2·72	0·54	0·176	0·008	3·64	2,300
First remelt		2·64	—	—	—	3·60	2,500
Second remelt		2·56	0·48	—	—	3·53	2,800
Pig iron	Charcoal	3·02	0·65	0·145	0·009	3·78	2,600
First remelt		2·84	—	0·139	0·009	3·78	3,650
Second remelt		2·86	0·65	0·131	0·009	3·72	4,000
Pig iron	Coke	1·95	0·94	0·520	0·029	3·85	2,500
First remelt		2·09	0·95	—	—	3·74	2,850
Second remelt		2·06	0·95	—	—	3·74	2,800
Pig iron	Coke	2·01	0·81	0·163	0·028	4·20	2,400
First remelt		1·99	0·78	0·176	0·033	3·83	2,450
Second remelt		2·03	0·71	0·173	0·038	3·80	2,300
Pig iron	Coke	3·63	—	0·45	0·023	3·55	2,200
First remelt		3·67	0·93	0·458	0·024	3·33	2,200
Second remelt		3·70	—	0·463	0·028	3·20	2,100

In view of these considerations, it is with added interest that one can compare the various types of melting furnaces in use in the foundry to-day, not only as to cost, but also as to the character of iron that one might expect to be able to produce therefrom, with a judicious selection of raw materials which can be dealt with in the respective furnaces.

It is useful in the first instance to examine the cost of melting in each case, apart from any merits which may be attributed to a particular type of furnace, and whilst it is difficult to give exact comparisons, owing to each type being generally of different capacities and melting rates, the following may be taken as approximate figures for such sizes as are in common use :—

Cupola	10s. to 15s. per ton.
Crucible	55s. to 90s. ,,
Rotary coal-fired	14s. to 16s. ,,
Rotary oil-fired	20s. to 25s. ,,
Electric furnace	50s. to 60s. ,,

Other factors to be considered are generally concerned with the raw materials to be used and the quality of metal required, whether for high-duty purposes or of special alloy composition for specific purposes.

The Cupola

Generally speaking, the cupola is still the main melting unit in the foundry, and the application of other types of furnaces for cast iron has been largely brought about by recent advancements in the metallurgy of this alloy. The cupola, however, is limited in its use of raw material which, on account of the intimate contact with the air and gases, is mainly confined to the heavier forms of iron, such as pig iron, cast iron, and steel scrap, whereas the open-hearth type of furnace is capable of dealing with lighter and cheaper materials, such as cast-iron borings and steel turnings, which off-set to some extent the greater cost of melting. The greater and more prolonged concentration of heat in these furnaces gives higher metal temperatures with refinement of structure, and permits the use of large amounts of ferro-alloys if required, and the choice of wider analysis in the raw materials without risk of irregular final composition.

The cupola has retained its original form of construction, though some modifications as pre-heating the air supply with the waste gases, as in the Griffin hot-blast type, supplying secondary air to promote more complete combustion, as in the Poumay system, or controlling the primary air by adjustable valves to ensure more regular combustion, as in the balanced-blast cupola, have met with considerable success where adopted. The theoretical operation of the cupola is too well known to warrant discussion here, although in practice certain fundamental rules must be observed to obtain maximum efficiency from the fuel employed. This can only be attained by ensuring complete combustion of the coke or its products, and the special cupolas referred to are designed to achieve this object or to make use of unburnt gases.

For complete combustion at least sufficient air must be supplied to burn the carbon in the coke ; the amount of the latter in the ratio of 10 to 1 is dependent on the capacity of the cupola selected to meet the requirements of the foundry, which will be about 11 lb. to 14 lb. of metal per sq. ft. of diameter at tuyere level. Theoretically, 1 lb. of coke (90% carbon) requires 10½ lb. of air, or about 140 cub. ft. for complete combustion, but in cupola practice it is found that an excess of 10 to 20% is necessary to achieve this object. Fig. 1 shows the effect of reducing the air supplied to a cupola melting iron for repetition work. The improved results obtained as the air was reduced to about 165 cub. ft. per lb. of coke is at once apparent.

The heat produced from 1 lb. of coke would melt and super-heat considerably more than ten times its weight of iron, in addition to raising the temperature of the slag, furnace walls, etc., and iron to coke ratios of 18 to 1 have been obtained with excessive air at increased pressure. Such conditions, however, bring about serious oxidation of the iron, increase the over-all iron losses, as well as silicon and manganese, and produce a metal of increased shrinkage.

More efficient production and utilisation of the heat available from the coke is obtained in the balanced-blast cupola, the design of which is now familiar to most foundrymen. In this type the object is to control the distribution of the air better and to provide a reducing atmosphere in the lower portions of the coke bed through which the molten metal passes, and where super-heating takes place. Both objects are accomplished by supplying sufficient air of relatively soft blast into the coke bed to provide carbon monoxide (CO) whilst the remainder of the air is projected in at higher levels to burn the carbon monoxide to carbon dioxide (CO_2).

The lower air is admitted through large-valved tuyeres, whilst a graded size of small auxiliary tuyeres of predetermined area and in two or three successive rows, gives progressive combustion of the CO to CO_2 and a gradual increase in temperature to the top of the coke bed. A higher pressure maintained in the wind belt secures better penetration of air from the auxiliary tuyeres across the section, giving a more uniform gas atmosphere and temperature at the melting zone. Such uniformity in gas composition minimises the oxidation of the metal, which, in the ordinary cupola, mainly takes place in the outer annulus where the gases are strongly oxidising and the heat is greatest.

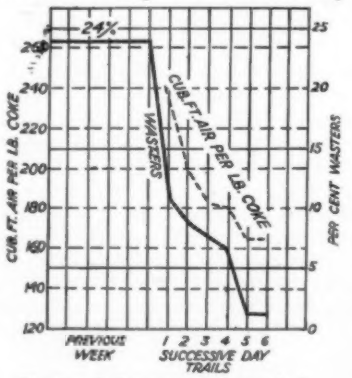


Fig. 1.—Influence of volume of air supplied to cupolau ponpr oduction.

The greater efficiency of combustion in the balanced-blast cupola is shown in the following gas analyses (by volume) of the top gases taken over several hours' run by Mr. J. E. Fletcher, the designer of the furnace, in two cupolas similar in every respect except that one was fitted with the special wind belt and tuyeres.

	Normal Cupola. %	Balanced Blast Cupola. %	Complete Combustion. %
CO_2	12·8	18·5	20·7
CO	8·9	1·4	0·0
O	0·4	0·6	0·0
N	77·9	79·5	79·3

The efficiency of combustion and better distribution of the heat in the balance-blast cupola was reflected in the coke consumption which was between 30 and 40% less than that in the original design of cupola.

(To le ccntinued.)

Heated-Treated Copper Castings Alloyed with Zirconium and Beryllium

Results of investigations are given which show that the alloys of copper and zirconium have high electrical conductivity, especially after suitable heat-treatment. In conjunction with beryllium, zirconium increases hardness slightly, but diminishes the degree of softening at temperatures which seriously affect the hardness of heat-treated beryllium-copper.

INVESTIGATIONS have shown that in alloys of copper and zirconium, zirconium hardens copper without remaining in solid solution to any appreciable extent. This characteristic suggests that copper castings might be hardened by zirconium without decrease in conductivity, such as is produced by most hardening agents. To investigate this question, some copper-zirconium alloys were made up and tested, and when it was shown that such alloys were susceptible to temper-hardening, an investigation was carried out by G. F. Comstock and R. E. Bannon* on the same lines as the research on the temper-hardening of copper-titanium alloys published in the December issue of *Metallurgia*, 1936.

In preparing the alloys, zirconium was added at a temperature of 1,275° C. in the form of a high-purity copper-zirconium alloy containing about 15% zirconium and less than 0·2% of silicon, iron, titanium, or aluminium, to pure copper melted in a clay-bonded graphite crucible in a gas-fired furnace. The casting properties of the alloys containing zirconium were better than those containing titanium, the tough skin being less in evidence on melting, so that the castings were cleaner. Test specimens were cast in the same manner as described for the titanium alloys and to the same pattern, and the heat-treatment, Rockwell hardess, and conductivity tests were also carried out in the same manner.

A first series of alloys was made with zirconium contents of 1·45, 2·4, and 3·24%, respectively. Two bars were made of each alloy, and one was maintained at 900° C. for two hours, and quenched in water. Specimens cut from each of the bars were heated at 260° 400°, 455°, 510°, 565°, and 650° C. for 1, 8, 16, 24 and 48 hours, respectively, at each temperature in order to determine the maximum hardness obtained by tempering. At each temperature, the maximum hardness was obtained from the quenched bar, tempered at 400° C., but it was necessary to temper for 48 hours in order to develop this hardness, and further tempering for 144 hours did not increase the hardness. The maximum hardness after 24 hours' tempering was obtained at 455° C. in each of the three quenched alloys and the hardness obtained together with conductity test made on bars subjected to the same treatment—*viz.*, quenched from 900° C. and aged for 24 hours at 455° C. are given in Table I.

TABLE I.

HARDNESS AND CONDUCTIVITY TESTS OF COPPER-ZIRCONIUM ALLOYS.

	Rockwell Hardness E.			Conductivity. %		
Zirconium. %.	As Cast.	Quenched.	Tempered.	As Cast.	Quenched.	Tempered.
1·45	64·5	53·0	76·0	61·1	56·7	75·5
2·4	73·0	65·0	79·5	55·0	50·0	68·0
3·24	76·5	71·0	84·5	44·0	41·2	55·0

With increasing zirconium content there occurs an increase in hardness after tempering, and a corresponding decrease in conductivity ; and in each alloy both hardness and conductivity are improved by tempering after quenching. While the maximum hardness obtained is not very high, the combination of hardness and conductivity is of interest.

An appreciable hardening occurs on tempering beryllium-zirconium-copper alloys, and as zirconium is much less costly than beryllium, it was thought that the combination of zirconium and beryllium in copper might offer some advantage over the straight beryllium-copper alloy. Accordingly, some copper alloys were prepared containing from 0·81 to 1·92% of beryllium, and 1·32 to 3·52% of zirconium. Preliminary heat-treatment experiments were carried out by water-quenching from 815° C. and tempering at 290°, 345°, 400°, 455° C., for 6, 12, 24 and 48 hours, respectively, at each temperature with the exception that the 48-hour treatment at 455° C. was not used. As a result of these tests, it was decided that 345° C. would be the best tempering temperature in general, and hardness and conductivity tests were therefore made after tempering at that temperature for 48 hours, both on unquenched specimens, and specimens quenched from 815° C. The results of these tests are given in Table II. When the results obtained are compared with results obtained from copper-beryllium alloys, it does not seem that much advantage is gained in the use of zirconium in conjunction with beryllium, since neither the hardness nor the conductivity is appreciably improved.

A series of heat-treatments was also carried out to determine to what extent zirconium improved the copper-beryllium alloys with respect to over-ageing. Samples from the alloys shown in Table II were hardened by quenching from 815° C., tempered for 48 hours at 345° C., and then subjected to a four-day treatment at 345°, 400°, and 485° C., respectively, and to 24 hours' treatment at 400°, 485°, and 565° C., respectively. From the results obtained it was apparent that zirconium was of value, for in every alloy containing zirconium the hardness was decreased less at the higher temperatures than in an alloy without zirconium, In the case of the alloy containing 3·52% zirconium the initial hardness was increased and then maintained even after four days at 485° C.

TABLE II.

HARDNESS AND CONDUCTIVITY OF COPPER-BERYLLIUM-ZIRCONIUM ALLOYS.

Composition.		Hardness Rockwell E.				Conductivity. %.			
Zirconium. %	Beryllium. %	As Cast.	Tempered, but not Quenched.	Quenched.	Quenched and Tempered.	As Cast.	Tempered, but not Quenched.	Quenched.	Quenched and Tempered.
1·46	1·56	85	113	82	116·5	21·8	31·2	20·8	36·2
1·32	1·74	87	116·5	79	116·5	19·2	28·3	17·7	31·2
2·98	1·49	88	109	86	115	20·6	25·4	19·8	29·1
3·52	1·14	85	92	85·5	96	22·6	24·1	21·7	23·7
1·36	1·92	85	119	78	119·5	18·1	27·0	15·8	30·5

Similar over-ageing treatments were given to conductivity test bars, and the Rockwell E hardness values and electrical conductivity determined after each treatment. The various heat-treatments were carried out consecutively, the specimens quenched at 815° C. and tempered at 345° C., being subjected to additional tempering for 24, 16, 7, 7 and 4 hours at 345°, 370°, 425°, 485°, and 540° C., respectively. From the results obtained, it was evident that, in the alloys containing zirconium, the hardness was maintained better at the higher temperatures. This beneficial effect, however, was not found with respect to the conductivity, as after heating at the higher temperatures, the conductivity being less in the alloys with zirconium than in the plain beryllium copper. From these results it is evident that the precipitated phase must be redissolved on overheating the alloys containing

* *Metal and Alloys*, 1937, Vol. 8, pp.106-109.

zirconium, the same as it is in the plain beryllium copper. The retardation of softening by the zirconium may be due to the prevention of growth of the precipitated particles which are too large to be rapidly dissolved at the temperature used for overheating, and yet not above the critical size for hardening, or a zirconium compound may be growing, during the overheating, from a sub-critical to an effective hardening size, thus tending to maintain the hardness, while a beryllium compound is passing into solution and reducing both hardness and conductivity.

The results of this investigation show that the alloys of copper and zirconium are of interest because of their high electrical conductivity, especially after suitable heat-treatment. When used in conjunction with beryllium, zirconium increases the hardness very slightly, but diminishes the degree of softening at temperatures high enough to affect seriously the hardness of the heat-treated beryllium copper.

Survey of Copper Lead and Zinc—Production and Consumption

Copper

IT is expected that the aggregate increase in copper production for 1937 is likely to exceed 1936 production by 400,000 tons, on the assumption that restriction is not reimposed. Activity in the engineering, electrical and motor trades continues and shipbuilding has shown a marked increase since last year; the total use of copper, lead and zinc in the world is expanding, this including rearmament programmes. Governments are evidently accumulating large stocks of copper in particular, a state which may be expected to continue for at least the next few months, and private consumers are maintaining their stocks as high as possible.

The monthly average of copper deliveries for January to April is 23,000 tons higher than the monthly average for 1936, the figures for April being 31,000 tons higher. The annual mining rate for copper in Northern Rhodesia is 220,000 tons and this may rise to 260,000 tons by the end of 1937. The Mufulira smelter, blown in in January, is gradually approaching its full rate of 80,000 tons; the Russian authorities plan to produce over 130,000 tons in 1937, an increase of 50,000 tons over 1936 production. Whether this production is fully achieved, remains to be seen, but a significant increase can be anticipated, and their smelting capacity will exceed 150,000 tons by the end of the present year. Increased production is also promised from Canada, where several smaller properties have been reopened and other smaller properties are expected to reopen. Increased production should be seen from Mexico and Peru. Spain must remain a negligible factor this year.

The U. M. Katanga Co. in the Belgian Congo is producing over 150,000 tons, an increase of 47,000 tons over 1936, and Chile is said to be now producing at the annual rate of 450,000 tons, an increase of 55·3% over 1936.

The increase of copper from other sources other than U.S.A., and the probable retention of the American copper tariff, can be expected to mean that whilst other producers cannot look to America as a market for copper, they can expect less American competition in the world market.

Lead

The production of lead is not expected to be greatly increased, a total increase of 100,000 tons being anticipated. In Jugoslavia, the Kopaonik mine should commence production by the middle of the year, with an estimated annual output of 10,000 tons, but the Zletovo mine will not be ready until early 1938 and will produce silver-lead concentrates on account of the low zinc content of the ore.

Increased production of lead is expected from Russia, although it is very doubtful whether the planned figure of 110,000 tons will be attained. Canadian output will probably exceed 200,000 tons, and total Australian yield may reach 235,000 tons, although the Mount Isa output of lead was rather lower in 1936 than the preceding year and no substantial improvement is anticipated this year.

From Tunis, Algeria and Morocco moderate increases are expected, whilst Mexico may regain the high level of eight years ago. No increase is expected from the United Kingdom, U.S.A. has not exported domestically mined lead since 1925 and no change is expected. The new concentrating plant at the Rammelsberg mine will increase German production.

Stocks of lead are equivalent to approximately one and one-half month's requirements, and output and consumption should remain comfortably in balance.

Zinc

Russian plans are for the production of 87,000 tons of zinc this year, compared with 55,000 tons in 1936; higher yield is expected from Australia, influenced by those deposits on which work was resumed in 1936; the increase in prices has stimulated production in the smaller countries; Mexico may reach its 1929 level for zinc production as well as for lead; the influence of the German Rammelsberg mine (sulphide ores) is bound to be noted, and the plant to produce zinc concentrates in this country is now ready. 50,000 tons of zinc is expected from the Lake Titicac working in Bolivia and the Rhodesian Broken Hill Co. plans to double its present 20,000 tons output.

It is not expected, however, that total output for the current year will exceed that of 1936 by more than 100,000 to 150,000 tons, and production and consumption of zinc should be in balance; especially as smelter capacity is adequate for the treatment of available supplies of concentrates. It may be that U.S.A. conditions will affect the market, as present indications seem to point to the necessity for the U.S.A. to import zinc ore or metal in the near future.

Canada's Base Metal Exports

The following table gives statistics relative to Canada's exports of the principal base metals during the twelve months ended March, 1937, as compared with those for the twelve months ended March, 1936. :—

Metal.	Twelve months ended March, 1947.		Twelve months ended March, 1936.	
	Quantity. Cwts.	Value. $.	Quantity. Cwts.	Value. $.
Aluminium (in blocks, etc.)	68,357	12,522,047	558,859	9,358,074
Aluminium (scrap)	19,656	242,366	26,881	361,413
Cobalt (oxide and cobalt salts, etc. (lb.)	490,965	572,545	464,124	480,633
Copper (in ore, matte, regulus, etc.)	521,729	3,963,652	378,973	2,024,180
Copper (blister)	—	—	544,845	4,174,227
Copper (in ingots, bars, etc.)	3,075,883	29,628,345	2,624,381	20,550,859
Copper (in rods, strips, sheets, etc.)	508,099	5,244,800	361,785	3,146,933
Copper (in rods, strips, sheets, etc.)	508,099	5,244,800	361,785	3,146,933
Lead (in ore)	103,132	340,609	79,502	231,624
Lead (in pigs)	3,439,935	13,438,592	2,860,854	8,055,150
Nickel (in matte or speiss)	601,905	10,835,789	661,947	11,907,860
Nickel (fine)	1,131,141	33,413,752	908,645	28,439,250
Nickel (Oxide)	57,315	1,632,653	38,660	1,297,270
Zinc (ore)	436,781	945,303	160,486	288,665
Zinc (spelter)	2,659,489	8,842,991	2,633,771	8,056,628

N.B.—Cwt. = 100 lb.

The Corrosion Problem and the Engineer*

By F. HUDSON

Factors which affect the corrosion of metals and which are intimately associated with either the properties of the metal or its service conditions, were discussed in the last issue; in this article the author deals with the prevention of corrosion, particularly the corrosion of iron and steel structures as affected by sea and natural waters.

ONCE some knowledge of the factors which affect corrosion is obtained, the study of failures and the economic practical prevention of corrosion assume much less terrifying proportions. The corrosion of iron and steel structures essentially depends upon whether or not a protective film can be formed and maintained on the metal surface. This film may be a product of a natural reaction between metal and environment or may be artificially applied as in galvanising, painting, etc. The first statement is exemplified by Staybrite steel, which by virtue of its composition has the property of rapidly forming in many liquids a dense adherent protective coating. Such a coating may not be visible to the eye, but it is none the less present, and has been actually isolated by Dr. Evans at Cambridge University. Ordinary steel also forms protective films in contact with various waters, particularly if the water tends to have an alkaline reaction, but usually the coating produced is only loosely adherent and easily susceptible to damage, not only by mechanical means, but by the action of many of the factors causing corrosion, as previously outlined. There is no doubt that the development and use of protective coatings will be the solution for obtaining increased corrosion resistance so far as the shipbuilding and heavy engineering industries are concerned, but in their development and use it must also not be forgotten that much will also depend upon the environment conditions and design of the structure requiring to be protected for complete success. The first aim should always be to try and see whether it is not possible to reduce the degree of corrosion by some modification of those factors causing corrosion.

For example, consider the question of the "graphitic softening" of cast iron in contact with sea-water or brines, such as the specimen shown in Fig. 8. This is undoubtedly the result of electrolytic action causing accelerated corrosion. Mention has been made of the fact that graphite is electro-positive to iron and so can accelerate attack. The structural composition of cast iron, containing as it does an intimate admixture of graphite and iron, is undoubtedly susceptible to this trouble, but normally will give many years of service if it has close grain, is adequately protected, and has a suitable environment. In this example only half the piston suffered attack by graphitic softening, and the increased attack has probably been caused by differential aeration due to leakage of water past the rings on one side.

The corrosion shown occurred within a few months of the piston going into service, and it should also be pointed out that the rings fitted were made of bronze. This, of course, tends to aggravate matters still further. Fig. 9 shows a photo-micrograph taken from the affected portion, and the action between the graphite flakes and iron matrix is clearly evident. The trouble in this instance was overcome completely by the use of a gunmetal piston fitted with ebonite rings and operating in a gunmetal-lined cylinder. This is an example of wrong design, which produced unsuitable environment and consequent premature failure, and is not directly a question of defective material.

If "graphitic softening" of cast iron is to be reduced to an absolute minimum, it is of paramount importance to prevent contact with widely dissimilar metals, particularly those metals electro-positive to iron, minimise turbulence as far as ever possible, and ensure the absence of stray currents. The substitution of "Staybrite" steel instead of bronze, particularly for valve and similar fittings, and the protection of the cast-iron body work by zinc spraying, followed by painting with suitable paint, is worthy of the closest consideration.

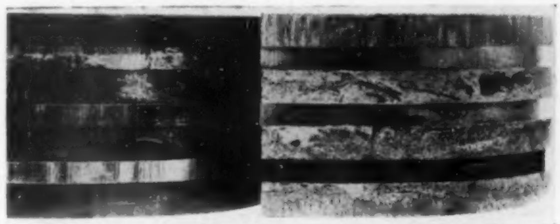


Fig. 8.—Graphite softening of a cast-iron piston.

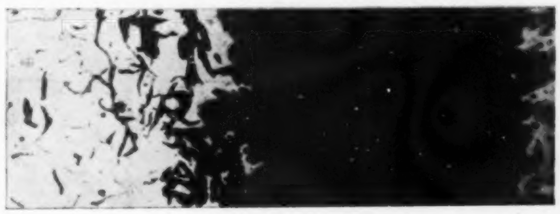


Fig. 9.—Photo-micrograph of the affected portion.

Mention might also be made of the possible improvement of the iron matrix by the addition of alloys to impart increased corrosion resistance. An electrolytic cell composed of, say, graphite and Staybrite steel, is not nearly so active as graphite and iron, and consequently if the iron matrix can be given similar corrosion-resisting properties there is hope for the elimination of "graphitic softening." This has to some extent already been accomplished with the production of austenitic cast iron, and is now being used by progressive engineers when price permits. Several applications of this material have been made in recent years, and a few selections are reproduced in Figs. 10 to 12.

Fig. 10 shows an electrically operated 8-in. pump valves for circulating harbour water to the ammonia condensers of a large refrigerating plant to recondition and ccol the air in the new Hong Kong and Shanghai Bank at Hong Kong. Made entirely from austenitic cast iron, to withstand complete submersion in harbour water. The pump plungers shown in Fig. 11 are for discharging acid water from gold mines. They have proved to be superior in service to stainless steel. The discharge valves shown in Fig. 12 are for sludge-disposal vessels. They are made in austenitic cast iron, with aluminium bronze fittings, to withstand sludge and sea-water action. It should be noted that greater liberties may be taken with this alloy in regard to the use of dissimilar metals, but this departure is not conducive to maximum service.

Another form of corrosion very common to many structures is shown in Fig. 13—namely, that of pitting.

*Continued from June issue-pages 51-4.

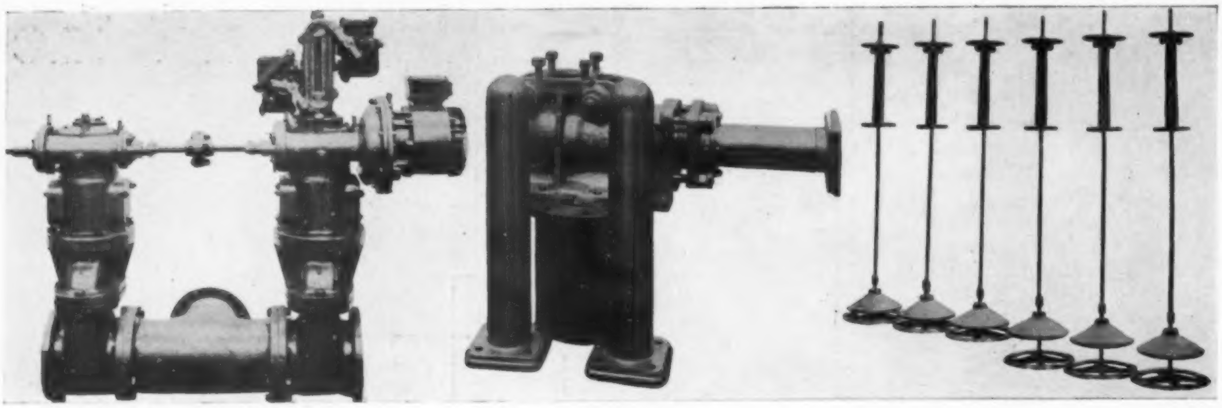


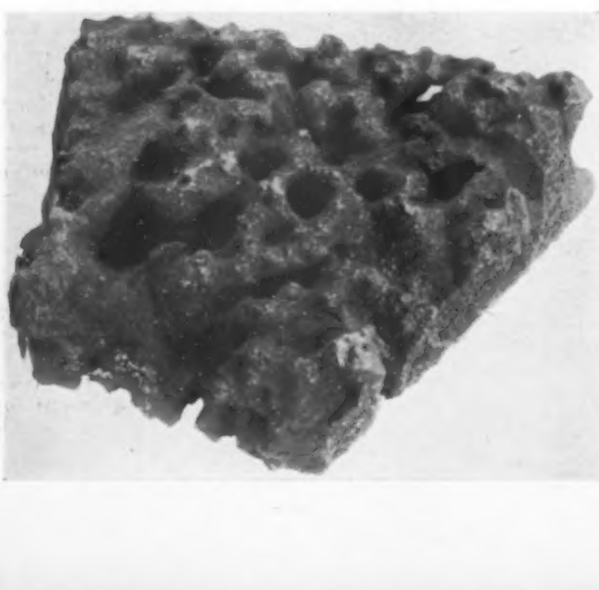
Fig. 10.—Pump valves for circulating harbour water. *Fig. 11.—Pump plungers for discharging acid water.* *Fig. 12.—Discharge valves for sludge disposal vessels.*
Applications of austenitic cast-iron to eliminate graphite softening.

This illustration indicates part of a large cast-iron valve which exhibited the defect locally, adjacent areas being entirely unaffected. This valve was of a type which should not be operated in a throttled condition, as this results in pronounced turbulence, together with the production of a vacuum, at the area affected. Due to certain conditions, however, the valve had to be throttled for long periods, and this caused a variation in the oxygen content of the water with consequent electro-chemical action brought about by anodic attack of the differential aeration type. This slide has been particularly included as the defect is apparently similar to the cavitation of propeller blades. It has been suggested that cavitation is caused by mechanical action, due to the hammering or bursting of small vacuum bubbles on the back of the blade. If this is correct, it is peculiar why metals like steel and cast iron, so much harder than bronze, should be actually more susceptible to pitting of this type. It is the writer's opinion that cavitation is entirely caused by corrosive influences.

TABLE VII.
EFFECT OF ABRASIVE LIQUIDS ON CORROSION.

Metal.	Brinell Hardness Number	Loss in Weight, Grms./Sq. Metre/24 Hours.				
		Mud and Water.			Water Alone.	Normal Loss in Aerated Fresh Water.
		First 100 Hours.	Second 100 Hours.	Third 100 Hours.	Second 100 Hours.	
Cast steel Low alloy steels Cast iron	137 to 512	96 to 162	93 to 161	—	37 to 69	7 to 10·5
Nitralloy steel	900	40	84	—	—	0·2
Stainless steel Staybrite steel Austenitic cast iron 30% Cr. iron alloy	166 to 444	2 to 16	1 to 16	—	0·1 to 2·4	Nil to 1·0
K Monel Bronze Brass Nickel alloys, etc.	45 to 321	15 to 16	8 to 30	10 to 21	0·6 to 4·3	0·08 to 0·27

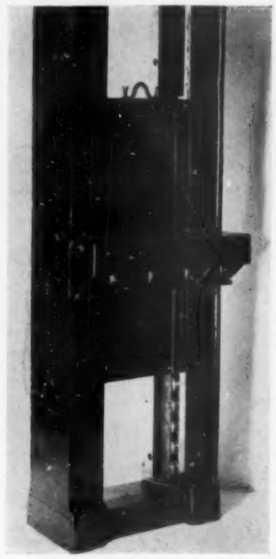
Fig. 13.—Part of a large cast-iron valve showing pitting.



Cavitation Due to Corrosive Influences

Some experiments recently conducted throw some light on to this problem. An investigation was commenced a few months ago in the writer's laboratory, in order to determine the most suitable metal for resisting wear by abrasive liquids, such as, for example, water containing sand, silt or mud. A machine was constructed, as shown in Fig. 14, which rotated specimens of various metals at 300 r.p.m. through a test mixture of mud and water. Table VII indicates the results obtained. It is interesting to note that the hardness of the metals tested bears no relation to the wear obtained, and that all specimens having good resistance to the abrasive action of the mud and water were primarily alloys having a high resistance to corrosion. Apparently the scouring action of the abrasive particles in the water removed the protective film on all but the corrosion-resisting alloys as fast as it formed, and so corrosion could proceed apace. Obviously, in these tests the solid particles in the water must be looked upon as an accelerator of corrosion, and not as an abrasive material, and increased resistance to wear must be obtained, not by the use of harder metals, but by the use of alloys having high corrosion resistance. It was also

Fig. 14.—Machine for testing resistance to wear by abrasive liquids.



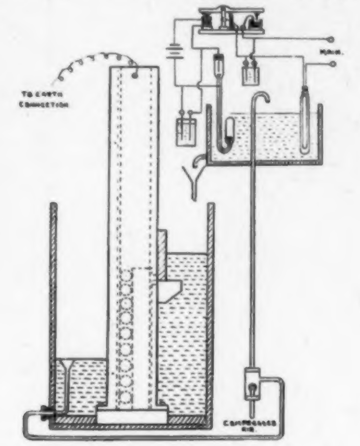


Fig. 15.—A model of a sluice-gate built to study corrosion, and a sketch showing the test procedure.

noticed that on the back of some of the specimens, away from the direction of rotation, the first sign of cavitation was evident, and again in all cases it was the lower corrosion resisting alloys which were affected, quite apart from the physical properties from the mechanical viewpoint.

The result of this last experiment suggests the value of using actual models for corrosion investigation work, and it should be possible by duplicating all variables to obtain results of considerable value and capable of practical application. In the design of ships, you make full use of models, and in this direction the co-operation of the engineer with the corrosion technologist would be of inestimable help. A study is being made in Kilmarnock of the corrosion taking place on large sluice gates by the use of perfect scale models, exact to detail not only in design but embodying the same materials of construction as its prototype, and reproducing as far as possible the environments of actual practice. Fig. 15 shows a model sluice gate built for this purpose, and a sketch of the testing procedure.

In most instances the water supply in these miniature systems comes from far corners of the earth, so every precaution is taken to prevent its contamination by any metal or material apart from that being tested. As a result, the container must be made of glass, paraffin wax is employed for foundations, and the auxiliary machinery for pumping, re-circulating, and the thermostat for temperature control, constructed also from glass. The water from the high level representing the reservoir flows through the gate into the low level representing the river, and is then re-circulated by air-lift pump to the storage tank, where it is automatically corrected for temperature by the thermostat, filtered and returned to the high level to repeat its performance.

Protective Coatings

Before concluding this article, some mention should be made of the use of artificially applied protective coatings. Space does not now permit of much being said in this direction, although the matter is of extreme importance and its application by industry has probably contributed more than any other to minimising the ravages of corrosion. There does appear, however, to be a woeful lack of knowledge in the engineering trade as to the quality and best use of such coatings. Obviously the first protective coating which comes to mind is the common one of applying paint.

Very little research has been conducted in this direction by the majority of engineers, and there is a real need for closer co-operation between the paint manufacturer and consumer. The position would undoubtedly be improved with the adoption of systematic paint tests by the engineering trade in conjunction with a more enlightened perspective of the properties required. At the present time it would seem that cost, covering power, ease of application, and personal opinion determine the merit of any one paint to a greater extent than its value as a means for preventing corrosion. Such a viewpoint does not permit, in many cases, of obtaining the most satisfactory measure of corrosion protection that the material is capable of affording.

The major aspect determining the selection of a paint coating should be the protection afforded the structure it is used upon, and quite a good indication of its value in this direction can be obtained by the Galvanic couple test, as illustrated in Fig. 16.*

The procedure followed is to cover a mild steel plate of defined area (8 in. × 10 in.), by dipping, with the paint to be tested. After the painted section is dry it is immersed in any particular solution, between two graphite electrodes of the same area as the sections under test. The small electric current generated by this couple is measured on a

*Digby & Paterson, (*The Engineer*, June 8th & 15th, 1934).

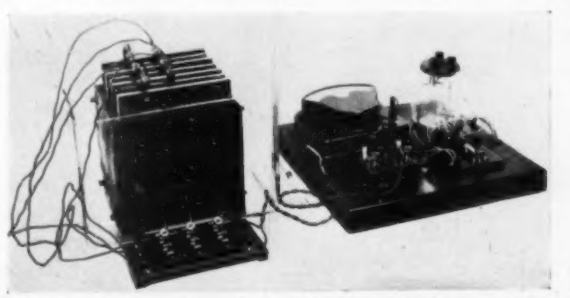
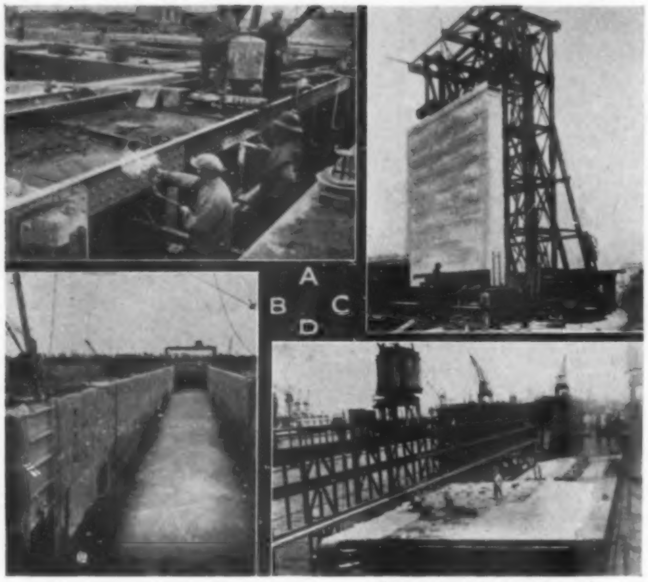


Fig. 16.—Galvanic couple testing for checking the value of paint as a protective medium.

Fig. 17.—Showing three plates which have been tested.



[By courtesy of Metallisation Ltd.

Fig. 19.—Application of metallic protective coatings.
(*a*) *Zinc-spraying the lock gates for the harbour Vauban a Strasbourg.*
(*b*) *The lock gate at the harbour Vauban a Strasbourg, entirely zinc sprayed, and then the lower portion painted with pitch.*
(*c*) *Zinc spraying the lock gate of the canal St. Denis a Paris.*
(*d*) *Zinc-sprayed dock gate for floating dock for the Port Autonome du Havre.*

sensitive galvanometer, the first reading being taken after half an hour with an open circuit and then at 24 hours' intervals, during which time the graphite plate and section under test have been in a closed or short-circuited state. The test is discontinued when (*a*) any sign of rust appears; (*b*) any abrupt alteration occurs in the current flowing.

Tests extending over a period of one year have indicated that given comparative conditions it is possible to grade

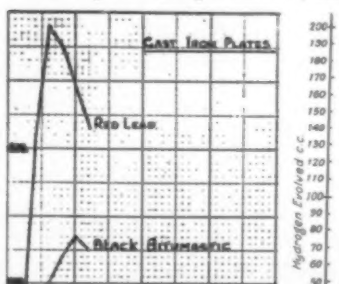


Fig. 18.—Some galvanic couple tests plotted for comparison.

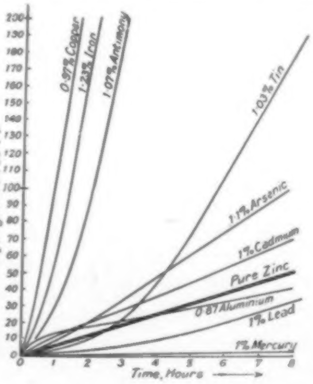


Fig. 20 (U. R. Evans).—Showing the effect of copper and iron on the corrosion-resistance of zinc.

the protection afforded by any number of paints according to time and degree of current generated. Fig. 17 illustrates the appearance of three plates after completion of the test, whilst Fig. 18 shows the results plotted graphically.

Reviewing the results obtained so far, it would appear that, as a class, paints having a white lead base afford consistently good protection against corrosion of iron and steel structures in contact with industrial waters. The grey paint shown in this slide conforms to this type. Certain bitumastic paints also give good service, but generally speaking, considerable variation in quality exists in this group which precludes a definite statement being made. The results obtained with red lead paints are disappointing, and the theory that they can act as an inhibitor of corrosion for iron and steel is difficult to believe. A point brought out by tests with this apparatus, quite apart from paint quality, indicates the importance of surface finish on the structure to be protected. It has been found, for example, that the better the surface finish, particularly as regards castings, the greater the protection afforded by any particular paint.

In addition to the use of paint, metallic coatings are used extensively for the protection of iron and steel against corrosion, and probably the application of zinc is most common and definitely advantageous. The application of the metal-spraying pistol in industry now permits very large structures to be coated, and Fig. 19 illustrates the application of this method to large dock gates. A zinc coating deposited by the metal pistol gives a surface particularly suitable as a base for paint, and when iron or steel is doubly protected by such methods excellent corrosion resistance is obtained. In galvanising by the hot-dipping process, the purity of the applied coating has an important bearing upon its corrosion resistance, and Fig. 20 indicates that the corrosion resistance of zinc is very seriously reduced by copper and iron. Needless to mention, the iron contamination is a point to be carefully watched, particularly in the galvanising of iron and steel articles.

The great danger in the use of another metal on iron or steel as a protection against corrosion is the risk of pinholes. The only metals which can be safely used in this respect are those below iron in the Electro-chemical Series, such as cadmium, zinc, or aluminium. With these metals, if the coating becomes perforated, little damage results, but if a metal such as nickel, tin, lead, or copper is used, which are above iron in the Series, very serious corrosion will accrue at the break in the surface, often leading to accelerated corrosion of the underlying metal and probably complete perforation of the structure.

The author desires to express indebtedness to the directors and management of Messrs. Glenfield and Kennedy, Ltd., for being able to give much of the information published.

A publication, produced by the Lead Technical Information Bureau, and published by the recently reconstituted Lead Industries Development Council, is in the form of a small booklet comprising a reference work primarily intended for users of the metal in any of its forms. The tabulated matter gives very useful information.

The introductory chapter is devoted to a brief survey of the uses of lead from prehistoric times to the present day and of contemporary sources of supply and methods of refining. Other chapters with illustrations are devoted to milled and cast sheet lead, sheet and ornamental cast lead, laminated lead and solders. Under the last-mentioned heading analyses are given of British Standard Soft Solders, tabulated according to the use for which each type is designed. The section on lead pipe includes a list of the sizes of pipe available in this country, with special reference to the standard sizes laid down by the British Standards Institution.

New developments in production are mentioned under the heading "Alloys of Lead." They include the ternary alloys containing cadmium, developed under the auspices of the British Non-Ferrous Metals Research Association and tellurium lead, the strength of which is latent when in the soft state, and is developed under stress or strain. The final chapters, on the properties of lead, are accompanied by a series of tables of data with regard to density, weight, thermal properties and the electrical, mechanical and other characteristics of the metal.

Lead Bulletin No. 2 will be sent post free on request by the Lead Industries Development Council, Rex House, 38, King William Street, London, E.C. 4.

Stainless Steels—their Composition for Industrial Purposes

"Although chromium steel was exhibited at the Paris Exhibition of 1900, its stainless properties were not recognised until many years later," said Dr. V. N. Krivobok, in a recent address to the American Iron and Steel Institute, in which he discussed the composition of stainless steels for industrial purposes. A brief summary of his address is given.

THE most important characteristic of stainless steels, that of resistance to corrosion, is derived from the addition of chromium, this being common to the 50 to 60 different modifications now available. Of these many classes, some differ in mechanical properties, others in their degree of resistance to corrosion and oxidation at elevated temperatures, and others contain various additional elements to suit them for specific applications. The addition of a substantial amount of nickel, for instance, improves resistance to corrosion and gives an alloy with different physical and mechanical properties. There are two distinct classes of stainless steel alloys—chromium alloys and chromium-nickel alloys.

In discussing the chromium alloys, Dr. Krivobok pointed out that straight chromium stainless steels, to commercial specifications, contain from 12 to 30% chromium, these being minimum and maximum content; and that the carbon contained in these alloys is usually between 0·07% and 0·30%, but may be increased to as much as 1·0% for wrought alloys, and even to 3·0% for alloys intended for casting.

Additions of increasing amounts of chromium to an alloy with constant but low carbon content will result in shifting temperature and concentration boundaries of allotropic changes, the basis of heat-treatment. When the concentration of chromium is sufficiently high, the A_1 allotropic transformation is entirely obliterated, and the alloys no longer show any effects after heat-treatment.

Straight chromium alloys should thus be subdivided into (1) those having properties which can be modified by heat-treatment; (2) those in which no appreciable change in either constituents or properties can be effected by heat-treatment; and (3) those alloys with various added elements to induce specific properties, but retaining resistance to corrosion.

Although no difficulty need be experienced in welding stainless steels, the service for which the welded structure is intended should be considered. If relatively high impact strength is required it is advisable to weld before heat-treatment. Correct annealing of the finished article should eliminate the danger of the phenomenon of stress corrosion, and also minimise the danger of diminished resistance to corrosion at or near the weld, relieving stresses that would be detrimental to mechanical strength.

Ferritic chromium alloys from 20–27% chromium have been found to be the most resistant to corrosion among the straight chromium group of alloys, but do not exhibit very high strength at high temperatures.

Chrome-Nickel Alloys

The addition of as much as 8% nickel to an 18% chromium alloy results in a metal of totally different mechanical properties and physical characteristics; the influence of nickel lowering the critical point in steel to below room temperature, or removing critical transformation altogether. A number of chromium-nickel alloys of "austenitic" type are now available, with structure, atomic space lattice, and many physical characteristics identical with high temperature austenite of carbon and low alloy steels. Austenitic alloys, however, possess different degrees of structural stability, depending upon actual concentrations of chromium, nickel, and carbon, and their ratios one to another. It has been found that variations in either chromium, nickel or carbon concentrations, within specified limits, have considerable influence on the physical properties attainable and also in such commercial processes as forming, bending, spinning, etc. Carbon and nickel contents have a decided influence on the rate of hardening during cold work, and upon the ductility which is available after a definite amount of cold deformation.

Proof stress (which has been defined as the stress in lb. per sq. in. which will produce, after being removed, a permanent set of a certain arbitrary value) is dependent upon composition, and can be made very high. After about 30% cold reduction, the proof stress of all of the alloys becomes 50% of the tensile strength. Austenitic chromium-nickel alloys are to be preferred for alloys possessing high tensile strength, high proof strength and highest corresponding ductility, but the ability to draw and form into intricate shapes and the ease of working are the function of composition.

Welding, riveting, and soldering may be used, but certain precautions in the selection and treatment after joining must be observed.

Structural Stability

Within certain ranges of temperatures the structural characteristics of these alloys may not remain constant. One structural change which affects the mechanical properties and certainly affects the corrosion resistance of the alloy, is that of "carbide precipitation." For alloys of variable composition, but of the same austenitic type, the maximum rate of carbide precipitation corresponds to a certain temperature.

Carbide precipitation has been solved by the addition of such elements as titanium, colombium, vanadium, and tantalum, with which carbon unites in preference to chromium. Some manufacturers recommend a "stabilising" heat-treatment at 1,400° to 1,500° F. for lengthy periods. Also, certain adjustments to balance the chromium, carbon, and nickel concentrations have proved satisfactory where only short-time heating (as in welding) is involved. Such welded structures can be used safely if high temperatures are not met in service.

One alloy of the austenitic chromium-nickel type contains the addition of 3% molybdenum, but certain manufacturing conditions might make modification necessary, as in one case where the final analysis became: Carbon, 0·1% maximum; chromium, 16·0 to 19·0%; nickel, 14·0% maximum; and molybdenum, 2·0 to 4·0%. This particular alloy is stated to have increased resistance to attack by sulphuric acid and sulphurous solutions. On the other hand, alloys with 20% chromium and 10% nickel, and with 25% chromium and 20% nickel, have given very satisfactory results.

The alloy containing molybdenum is certainly less liable to the type of corrosion generally known as "pitting" or "pinholing," which is the formation of either very small or, at times, quite large holes, which may penetrate through the whole thickness while the material immediately adjacent remains unaffected.

Alloys containing approximately 3% tungsten in both 12–14% chromium and 16–18% chromium series, have been developed in recent years, and tungsten is at the moment the only element that has considerable influence in increasing the strength of the alloy. Some promise is shown by boron,

but further investigation is needed. While additions of nickel and copper increase the hardenability of straight chromium alloys, the elements titanium, colombium, and aluminium render alloys practically unhardenable after standard heat-treatment.

Recently it was found that about 1% of titanium is very helpful in inducing grain refinement in the ingot. It is believed that the behaviour of metals in corrosive media is dependent upon the properties of the oxidised film formed at the surface, the continuity of the film, its chemical stability, its characteristics, such as brittleness or toughness, hardness, or ability to permit diffusion of oxygen through it. Until it is known what properties the protective film must possess, the problem of corrosion will remain.

Finally, the usual classifications of forms of corrosion are: (1) General chemical attack, direct; (2) local, or pitting; (3) local, galvanic cell, two metal; (4) local, concentration cell; and (5) stress and fatigue corrosion.

Dr. Krivobok concluded with a tribute to the work of modern metallurgists, upon whose shoulders, he said, the ingenuity of fellow-workers in other industries often places a heavy responsibility.

Effective Use of Metal-Cutting Tools

THE determination of factors governing the effective use of single-nose metal-cutting tools, as for lathes, planers, shapers, etc., was the subject of a paper by R. C. Deale*; the factors considered being those of tool form and, material, method of heat-treatment, material machined, depth of cut, speed of feed, speed of cutting and tool life. Formulæ were developed, and standard practice established for some others that are not susceptible to mathematical analysis.

As an instance of the savings possible through the application of some of the methods developed, a change in the procedure for hardening high-speed steel tools in all large machines are quoted, the results showing that tools that were hardened according to the new standard, under uniform conditions of tool form, depth of cut, rate of feed, metal removed and tool life, could be run at cutting speeds approximately 20% higher than those tools hardened according to the usual shop methods. The resultant gain in production could be obtained at no additional cost, as the equipment used for both hardening and utilisation of the tools was unchanged.

The cutting speed for uniform tool life was calculated by the formula, established by the experiments of the A.S.M.E. Special Research Committee on Cutting of Metals: $VM^{0 \cdot 100}$ = a constant, where M = tool life in minutes, and V = cutting speed, in ft. per min.

Of the various formulæ developed, that relating to cutting-speed is certainly one of the most useful:

$$V = \frac{K^1 \times K^2 \times K^3 \times K^4 \times K^5 \times K^6 \times K^7}{T^a \times L^{bT} \times M^n}$$

where a = exponent, determined experimentally, depending on metal cut, regardless of tool material; b = exponent, determined experimentally, depending on the tool material; K^1 = constant, determined experimentally, depending on the tool material; K^2 = constant depending on the hardening treatment of a steel tool. For tools not given any heat-treatment, such as Stellite and cemented carbides this term drops out; K^3 = constant depending on tempering ing treatment of a steel tool. This term also drops out for Stellite and cemented-carbide tools; K^4 = constant depending on machinability of metal cut; K^5 = factor depending on kind and quantity of cutting fluid used; K^6 = factor depending on rake angle of tool; K^7 = factor depending on type of cut, such as roughing, finishing, parting, forming, etc.; L = total active length of the cutting edge of the tool in contact with the work, in; M = tool life to complete failure, min. This includes only the time when tool is actively engaged in removing a chip from the work-piece up to point of failure, which will vary according to practical shop requirements of a given operation; n = exponent, determined experimentally, depending on tool material, metal cut, and type of tool failure; T = average chip thickness, in. Where the tool has a nose radius, or where the point angle is appreciably greater than by 90°, this is equal to chip area divided by total length of the engagement. When the point angle is 90° or less, average chip thickness may be taken as equal to chip area divided by active length of front cutting edge; V = cutting speed, ft. per min., measured on the uncut section of the work ahead of the tool.

All available experimental data have been analysed in developing that formula. Deviations between values computed by the formula and those obtained experimentally range from 3% to 8%, which the author contends is within the limits of experimental error. It should be noted that both constants and exponents change according to the change of the metal cut, as from steel to bronze. Further experiments are needed before the formula quoted could be applied to cutting of non-ferrous metals.

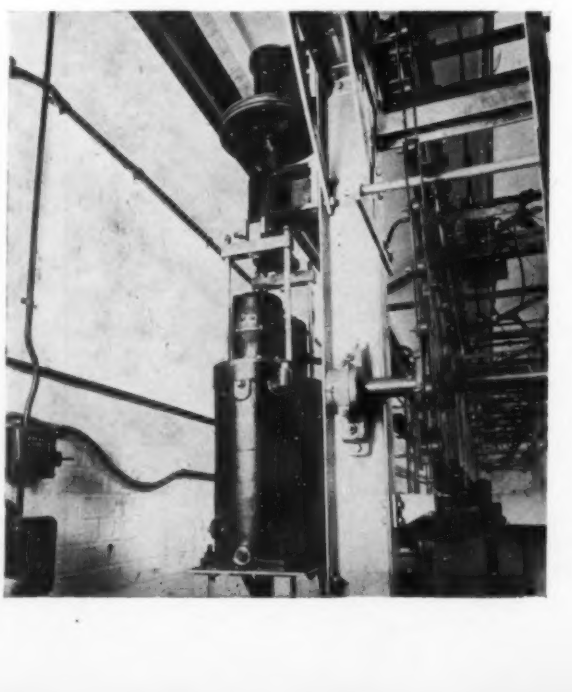
The paper also gives useful formulæ for heavy roughing cuts in steel with chip thickness exceeding 0·015 in., without cutting fluid and using well hardened high-speed steel tools; for cutting steel; for calculating the tangential component of the cutting pressure; and a formula has been established for ascertaining the interval at which a tool should be reground to give minimum overall machining costs. One very interesting factor established was that, for rough turning steel with high-speed steel tools, the total cost of operating machine tool during cutting period between grinds equalled seven times the total cost of changing and grinding a tool, including tool cost per grind. Breaking strength and deflection of hardened high-speed tool; most economical feed, speed and depth of cut, are also dealt with in detail.

* R. C. Deale, *Mech. Eng.*, June, 1937. Pp. 413-414.

B.T.-H. Thrusters Facilitate Control

RECENT installations of thrusters made by the British Thomson-Houston Co. Ltd., include two particularly interesting applications. One is shown in the accompanying illustration where two of the recently developed largest size thrusters, are shown installed in a modern electro-plating shop. Operation of the plant is automatic and the thrusters are applied to actuate the travel of the transfer motion gear which lifts the parts being treated from one vat to the next. Time lags on the power stroke of the thruster enable the transfer time to be adjusted to synchronise with different plating speeds used.

B.T.-H. thrusters installed in an electro-plating shop.



The International Foundry Congress

The recent Paris Congress is briefly described and some of the technical subjects discussed

THE close relations which exist between the foundry technical associations in various countries are largely due to the International Foundry Congresses which have been held annually for the past twelve years. This year's Congress was held in Paris and was organised by the Association Technique de Fonderie of France under the presidency of M. Achille Brizon. The Congress was attended by about 650 members and ladies from seventeen countries, Great Britain being represented by a party of 35 members of the Institute of British Foundrymen and 15 ladies.

The visitors were welcomed at the opening meeting on June 18th by M. J. Julien, Under Secretary for Technical Education, on behalf of the French Government, and by M. Brizon and M. M. Olibier on behalf of the foundry industry of France. In accordance with the usual practice of these Congresses, the response to the welcome was made on behalf of all the visitors by the President of the International Committee of Foundry Technical Associations, who this year is Mr. W. Delport, of London. Mr. Delport holds this office in his capacity of European representative of the American Foundrymen's Association. The opening ceremony was followed by an address by M. H. Luc, Director General of Technical Education, in which he reviewed the facilities for technical education for the foundry industry, which exist in France. M. Luc showed how these facilities could be linked up with a system of practical training and apprenticeship.

Technical Sessions

Nearly fifty papers were presented and discussed, duplicate sessions being held throughout the Congress. The subjects of the papers covered alloy and other high duty irons, aluminium foundry practice, moulding and investigation and various aspects of foundry organisation and management. There were also papers giving a general review of certain branches of the industry such as the official Exchange Paper of the Institute of British Foundrymen by H. H. Shepherd, which was a comprehensive account of malleable cast iron melting practice in Great Britain and the American Foundrymen's Association Exchange Paper by P. Eddy on the subject of "Irons for Industrial Motor Vehicles." In this paper the author gave the analyses, melting procedure, physical properties and details of heat treatment of a number of irons for cylinder blocks and liners, exhaust pipes and many other important automobile castings.

A duplex melting process (cupola and Heroult electric furnace) is employed for the more important cylinder blocks. The analyses for the various mixtures employed for these castings are within the following ranges, total carbon from 3 to 3·3%, nickel from 0·35 to 2%, chromium 0·25 to 0·65% and in certain mixtures 0·15 to 0·75% of molybdenum is added.

Two papers by British authors, Dr. A. B. Everest and G. T. Lunt reviewed the position in Great Britain of Ni-resist and high quality special irons respectively.

In a paper on silicon and tin additions to grey iron, Dr. Valenta and N. Chvorinor of the Skoda Co., showed that the introduction of addition to grey iron mixtures not only has a definite action upon the properties of the iron by modification of the chemical composition, but also has an instantaneous action upon the physical state of the liquid iron. The addition of ferro-silicon produces normal graphitisation in low carbon irons (2·6 to 3% carbon) and at the same time increases their physical properties. The effects of tin additions are not completely understood. The influence of 0·5% of tin upon the hardness is about the same as that of 1·2% of nickel and 0·35% of chromium, but its influence on resistance to wear is much greater. When larger amounts of tin are added, the mechanical properties,—transverse and tensile,—are appreciably reduced, while the resistance to wear tends to increase.

A systematic study of the causes of defects in castings was outlined in two papers by Professor Portevin and A. Debar rspectively, the former dealing with defects due to the metal, and the latter with those due to the mould. In the course of the Congress, an International Committee was formed on the suggestion of Professor Portevin to continue a systematic study of defects and other causes and some valuable data can be expected at a future Congress.

The development of the highest possible mechanical properties of castings by careful study of their design and shape was the subject of a paper by J. F. C. Giradet. After discussing the well known complications which are introduced by cooling, contraction, segregation, etc., the author showed how resulting weaknesses could be modified by slight modifications of shape and design.

An interesting paper by M. Olivo, an Italian author, dealt with a new method of moulding radiator elements on a mass production basis. The moulds are split vertically and the various processes of moulding, coring, and casting are carried out on the well known conveyor principle. It is claimed for the vertical method of moulding, that castings are less liable to be defective as gas and impurities collect in the "head" of the casting, and also because cores can be secured with the use of the minimum use of chaplets; economy of space is claimed as a further advantage.

The founding of light alloys was the general subject of a special session and included a communication by R. Perret on defects in aluminium castings due to incorrect pouring and gating. Suggestions were given on the size, shape and disposition of gates and risers, designed to eliminate such defects. The solidification of aluminium castings and its effect upon grain size and the mechanical properties of the casting, was discussed in a paper by by Dr. R Irnann, a Swiss author.

A comprehensive communication on the properties of moulding sands was presented by Professor Pisek, President of the Czechoslovakian Foundrymen's Association, and B. Holdman and included tables and graphs, illustrating the results of tests on 48 different types of sand. As a result of these tests the authors have established formulæ showing :—

1. The relation between (*a*) cohesion and (*b*) grain size and argillaceous matter.
2. The relation between (*a*) permeability and (*b*) grain size and argillaceous matter.
3. The relation between (*a*) permeability and (*b*) grain size and cohesion.

A session on organisation and management was held in conjunction with l'Association Amicale et Mutuale de Fonderie, and included an interesting review of the organisation of the foundries of the French State Railways at Sottville.

Works Visits

Visits to works form an important feature of International Foundry Conferences and a number of visits to

foundries in the Paris area were arranged during the mornings. A large number of members also took the opportunity to take part in a visit not primarily of foundry interest, namely to the well known railway locomotive testing bench at Vitry-sur-Seine. Visits were also paid to the Ecole Centrale des Arts et Manufactures, one of the great technical institutions of France, and to the Foundry High School, which is now known internationally for its work in training foundry executives and technicians.

At the closing session of the Congress, a bronze medallion was presented to Mr. J. Leonard, President of the Belgian Foundrymen's Association, and Past President of the International Committee of Foundry Technical Associations, as a recognition of his services to the industry. On behalf of the Czechoslovakian Foundrymen's Association, Professor Pisek presented to the French Association, a small bronze statuette with the coat of arms of the Czechoslovakian Association. The Conference concluded with a banquet at the Pavillon Daphine, at which M. H. Luc presided.

THE PARIS EXHIBITION

The International Exhibition will be a worthy successor to the International Exhibitions which have been held in Paris from time to time during the last two or three generations. The principal portion of the Exhibition is laid out on Champs de Mar, and on the grounds in front of the Trocadero, which has been demolished, new buildings having been erected in its place. The Eiffel Tower forms a wonderful centrepiece for this portion of the Exhibition.

Other sections are laid out in various locations on the banks of the Seine, and are connected, partly by the existing quays and partly by special overhead roads and bridges which have been constructed to interfere as little as possible with ordinary traffic. The layout is naturally somewhat scattered, and unfortunately labour difficulties have delayed the work, so that the Exhibition will not be completed for some weeks.

A representative group of locomotives and rolling stock is open for inspection in the palatial railway transport building, this group includes a streamlined electric train from Italy ; a sumptuous long-distance train from Poland, which includes a bathroom car ; and refrigerator cars destined for the London-Paris train ferry services ; representative locomotives—Diesel, steam, and electric—are also shown.

A number of light engineering products are on view in the striking pavilion of Italy, whilst several interesting castings and forgings from the Skoda Work were being fixed in the almost completed Czechoslovakian Pavilion.

The United Kingdom pavilion is now open ; it contains however, little of interest to the engineer, and its interest to the metallurgist is mainly confined to some wonderful examples of silver-ware.

Some Technical Data Presented

Some valuable information and data were presented at the technical sessions and, although it is not possible here to review all the papers, a number summarised in the following notes will be of interest.

MALLEABLE IRON MELTING PRACTICE

In dealing with malleable iron melting practice, both from the retrospective and prospective points of view, Mr. H. H. Shepherd stressed the importance of analytical control of pig iron, steel and wrought-iron scrap and malleable cast-iron scrap, and discussed the so-called inherent properties of pig iron in the light of modern views and theories. Correlated information with regard to malleable cast iron is comparatively scarce, during the past 20 to 25 years only three or four text books have been published and, of these, one of the most valuable is *La Malleable*, by Maurice Leroyer. Mr. Shepherd surveyed that phase of malleable iron practice concerned with melting procedure as employed for the manufacture of blackheart and whiteheart castings, after dealing with their commercial possibilities and the world output. He also gave a proposed definition of malleable cast irons.

Having regard to the enormous developments that have taken place in connection with raw materials, testing and control of foundry sands, including synthetic sands, these factors were included in the survey. Progress in the use of steel scrap was also dealt with, together with typical practices and the deleterious effects of chromium in malleable iron which is required to possess maximum strength with ductility were reviewed. The effects of various elements were dealt with, the influence of manganese and sulphur being considered in relation to the raw material and the finished product.

The crucible, cupola, open hearth, electric and rotary furnaces were all considered. The importance of complete control of all stages in cupola melting practice were pointed out, the advantages of cupola melting for certain conditions were elucidated, and the economy aspect of the cupola when used with other melting units to produce the best possible quality malleable cast iron of either blackheart or whiteheart types was detailed. Among the recent developments of cupola practice mentioned was that of the balanced blast system. Modern air furnace practice, the importance of refractories and their relatively high cost and development were other subjects covered, and the various duplex and triplex methods were studied, particulars of plants operating successfully on these methods being given.

In regard to the thermal efficiency of melting furnaces it was established that air furnaces have low thermal efficiency but that high efficiency can be obtained from both the electric and the cupola furnace. Reference in a more general manner was made to the modern developments of the rotary furnace fired with pulverised coal, gas or oil, with regard to their application to the production of malleable irons.

Pouring temperatures and superheating formed a most valuable section, the practical advantages of superheating of the molten metal being dealt with, and the limitations indicated. It was contended that it is necessary to consider superheating and pouring temperatures separately. Pinsl has expressed the opinion that there is an optimum temperature of pouring by which the best physical properties of each composition of iron are obtained, and that this temperature is independent of the temperature of superheating.

There is a critical interval of temperature of pouring, above which physical properties diminish, and this was fixed at 1,470° to 1,565° C. The researches of Di Giulo and White showed that there was no benefit from superheating unless a temperature of 1,480°C was attained and that physical properties continue to improve until a temperature of 1,665° C. is reached, after which a sudden cessation is encountered.

Another interesting point raised was that it is sometimes necessary to use cooling devices to accelerate freezing, this resulting in a finer grain, especially in thinner sections.

Three types of iron were studied for this purpose, as follows :—

	Carbon.	Silicon.	Temperature, ° C.
1.	2·75	1·15	1,495–1,593–1,631
2.	1·40	1·50	1,574–1,732
3.	1·50	1·70	1,565–1,665–1,759

No. 1 corresponding to a standard metal composition in a malleable iron foundry and Nos. 2 and 3 were made in an oscillating electric arc furnace. All tests were made and poured in same conditions and at same temperature—1,495° C. For the first iron, increase of temperature from 1,495° to 1,593° C. reduced the duration of the first and second stages of graphitisation by 10-12% ; and increasing the temperature to 1,631° C. achieved complete malleabilisation with a reduction of 28% in the period of solidification. The superheating of irons Nos. 2 and 3 from 1,732° to 1,749° C. permitted a reduction of 40% for the total

period of solidification, the greatest diminution being seen at the second stage of graphitisation.

The temperature of superheat which improves ductility is in the region of 1,630° C., better results being seen at that temperature than at 1,593° C. ; similar superiority was observed in the case of the low carbon and high silicon content metals heated to temperatures higher than 1,665° C.

The question arises : Is the interval of critical temperatures for malleable iron, in general, between 1,600° and 1,665° C. ? It is interesting to note that Di Giulo and White have indicated the maximum critical temperature of superheating, for grey iron, at 1.665° C., which bears out the foregoing observations.

COMMERCIAL PRODUCTION OF REFINED PIG IRONS

In his paper on the commercial production of refined pig irons for high duty castings, Mr. G. T. Lunt defined refined pig irons as those pig irons prepared by retreating blast furnace pig irons with the object of improving their qualities, properties and characteristics for special requirements. This refining may consist of the removal of various undesirable consituents, or the admixture of other and desirable constituents, or of special treatments according to the nature of the purpose for which the iron is intended.

He outlined the methods used in the latter half of the eighteenth century and showed that the term " refined iron " was then applied to a product which represented an intermediate stage between grey pig iron and malleable wrought iron. The gradual displacement of the earlier methods of wrought iron production, first by the puddling processes and later by the Bessemer, crucible and open hearth steel making processes, has brought about a change in the use of refined pig irons ; to-day, whilst there is a certain amount of refined pig iron manufactured for use in the production of wrought iron, the bulk of the refined irons is used for the production of castings, particularly whiteheart malleable castings, and those of high duty character, such as are used for cylinders and rolls.

Classification of Refined Pig Irons

Developments in the manufacture of malleable castings and improvements in the qualities and characteristics of grey cast irons have opened up other fields, whilst the high standard achieved in the development of refining processes has extended the commercial production of refined irons, and those produced to-day, for commercial purposes, form four broad classifications.

1. *Refined Malleable Pig Irons.*—For the production of malleable castings, chiefly of the whiteheart type. These irons are low in silicon content and possess fracture characteristics varying from white, through the ranges of mottlings to hard grey fractures. There is now a noticeable tendency to regard the chemical composition alone as the criterion of suitability for specific purposes, although quite a number of foundries still attach a great deal of importance to the fracture characteristics. In the works with which the author is connected, refined malleable pig irons are produced to meet fracture requirements and to close limits of chemical composition, ten different fractures being recognised, the latter being :—

2. *Refined Cylinder Pig Irons.*—For use in the production of high grade grey iron castings. Includes all those irons produced to guaranteed chemical compositions and under such conditions as ensure uniformity of composition and of physical and mechanical properties, covering a wide range of specifications. These irons are used extensively for cylinder and cylinder component castings of engines, pumps, compressors, etc.

3. *Special Refined Pig Iron Qualities.*—A broad classification which includes those pig irons prepared synthetically to match in compositon and properties blast furnace irons such as Swedish irons and Genuine Cold Blast Irons, also irons prepared by special processes, having special structural characteristics, fine graphite structure, inoculated irons, irons possessing special chilling properties, irons with specially high total carbon contents, and irons specially free from sulphur, arsenic or phosphorus.

4. *Refined Alloy Pig Irons.*—Covering a wide range of irons containing such elements as copper, nickel, chromium, molybdenum, titanium, tungsten and vanadium ; guaranteed accuracy and uniformity of the chemical composition being possible by the use of carefully controlled refining methods.

Refining Methods

Modern methods of refinement vary considerably. The simplest and oldest is the direct use of the cupola furnace, the result being obtained by melting together suitable blast furnace pig irons and, if necessary, steel scrap. Reliance is placed upon the metal mixture but the use of the cupola alone is limited in the facilities it affords for the treatment of the metal in molten state. A development of this method is the use of duplex processes, the initial melting being done in a cupola and the molten metal received in an oil fired receiver or furnace, electric furnace or pulverised fuel furnace. One of the principal treatments which can be carried out in the oil fired receiver is the degasification process.

Another method is that of melting in oil fired or pulverised coal fired rotary furnaces, the latter being more common, as it enables superheating and treatment of the molten metal to a considerable extent to be undertaken in the one furnace. Open hearth furnaces of the regenerative type offer similar results and simple reverberatory type furnaces have the facility of melting down materials in large unit masses such as scrap rolls and ingot moulds. The Bessemer or Tropenas type converter is also adapted for the production of refined irons, the changes in composition being produced by Bessemerizing actions and the after treatment of the molten metal carried out in the converter body and also in the ladle.

It would appear that the duplex processes are the most satisfactory, allowing superheating of the metal should this be necessary, giving adequate facilities for treatment of the metal with special slags for the removal of sulphur and arsenic, permitting the use of degasification and vibration processes and ensuring the thorough incorporation of any alloy additions.

Although most refined pig irons are cast in sand moulds, there is an increasing tendency toward the use of metal moulds, the latter inducing a close fracture even with pig irons having a naturally open fracture, and tending to mask any intrinsic tendencies to open or close grain in

	Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
Grey Chilled Grey	2·90–3·20	0·90–1·40	0·06–0·10	0·07 max.	0·25–0·40
Grey Mottled Soft Mottled Medium Mottled	2·90–3·20	0·70–0·95	0·06–0·10	0·07 max.	0·25–0·40
Hard Mottled Hard Hard Mottled	2·90–3·20	0·65–0·85	0·07–0·11	0·07 max.	0·25–0·40
Spotted White Tick White	2·90–3·20	0·55–0·75	0·07–0·12	0·07 max.	0·25–0·40
White	2·90–3·20	0·35–0·60	0·09–0·15	0·07 max.	0·20–0·30

the iron. Freedom from sand, convenient size and close fracture should appeal to the foundryman requiring clean, close and strong castings.

Applications

Refined pig irons are finding increased use in the production of general castings and enable the foundryman to meet the demand for castings to exacting specifications and free from internal defects. Refining processes enable the desired compositions to be achieved, and secure these initially fine grained, fine graphite structures with lower total carbon and phosphorus contents, and their use exclusively or in admixture with blast furnace pig irons in foundry mixtures has now become a recognised method of producing general castings of high quality.

The table which follows shows a system of metal mixing which may safely be employed without departure from standard practice for grey irons.

Cupola melting is used for large castings, and any trouble due to contamination by other metal in the cupola has been overcome by melting the alloy addition or nickel-copper-chromium pig separately in a crucible and adding it in the molten condition to the ladle of iron tipped from the cupola. The use of a high carbon pig iron will save the difficulty of holding the carbon content at a sufficiently high level.

Ni-Resist is generally cast in dry and green sand moulds, following the usual brass foundry practice, and is also cast successfully by the centrifugal method. The metal is readily machinable and has a tensile strength of 13–15 tons per square inch, with an elongation of some 2–3% in the tensile test. Excess carbides which may result from chill in thin sections or from a high chromium content can be broken down by annealing at a temperature of about 900° C.

CORRECT METAL PRACTICE.*

Mixture No.	Cupola Mixture.	Calculated Chemical Composition.					Physical Tests.		Specification Conformed to	Suitable for Castings.
		Tot. C.	Si.	Mn.	Su.	P.	Tensile Tons/In.	Transverse Tons/In.		
2	15% Scotch .... 15% Refined ...... 40% Returned scrap 20% Foreign scrap 10% Steel scrap ..	3·25	1·70	0·70	0·08	0·65	14·0	25·5	B.S. 1 No. 321/28 S. Bar, Grade A. Also British Admiralty Grades 2.	Flywheels, rotors, Couplings, Crankcases, and medium sectional work not required to stand high pressure.
3	25% Foundry ..... 25% Refined ...... 40% Returned scrap 10% Steel scrap ...	3·20	1·65	1·0	0·10	0·55	15·0	26·5	Test Bar sizes as above.	Castings similar to above needing a slightly tighter metal, giving greater wear and pressure resistance.
4	50% Refined ...... 40% Returned scrap 10% Steel scrap ..	3·0	1·4	0·95	0·10	0·45	16·0	28·0	Test Bar sizes as above.	Turbine casings, cylinder liners, covers and heads, pistons, gear-cases, valve sleeves, castings of heavy section to withstand heavy wear and pressure conditions.
5	50% Refined ...... 40% Returned scrap 10% Steel scrap ...	3·0	1·15	1·0	0·10	0·45	17·0 With Nickel 18·0 and over.	30·0 With Nickel 32·0 and over.	For special high test requirements.	Castings as above. Valves and work having to conform to special service conditions.

NI-RESIST CAST IRON

The development and application of Ni-Resist alloy was presented by Dr. A. B. Everest, who described Ni-Resist as a typical member of the austenitic cast iron group. He dealt with the composition and production of the metal, its properties, corrosion resistance, erosion resistance, electrical qualities and its application for cylinder liners and in the electrical and mechanical fields.

The composition usually adopted in Great Britain is: total carbon 2·8–3·1%, silicon 1·5–2·0%, manganese 0·7–1·2%, sulphur 0·12% max., phosphorus 0·3% max., nickel 14·0–16·0%, copper 6·0–8·0% and chromium 2·0–6·0%; but for certain applications where the presence of copper is not desirable this element is omitted and the nickel increased to 20–22%.

Ni-Resist is most commonly produced in this country by mixing a suitable pig iron or scrap with the necessary alloys, the latter generally being in the form of a specially prepared alloy pig of nickel-copper-chromium; but scrap Monel or even virgin metals are sometimes used for the addition. Melting is carried out in crucibles, air furnaces or rotary furnaces, generally of the oil-fired type. For special applications, such as for automobile cylinder liners, some foundries use small electric furnaces.

* J. L. Francis. (I. & S. Ind., 11-1936.—130.)

Major Properties of this Alloy

Its resistance to corrosion is of an exceptional character being some 500 times better than plain cast iron when in contact with weak sulphuric acid and having very good resistance to attack by weak hydrochloric acid, or to attack by caustic alkalis, many organic acids, salts and industrial fluids. Ni-Resist is largely used in the chemical and process industries for pipes, valves, fittings, pumps, filter plates and meter parts; for the castings in the ends fitted to wooden rollers used in dye vats and where a degree of malleability also is required; in the construction of pumps handling various liquors in the paper industry, for meters handling petroleum products and for various fittings in soap works.

It possesses good resistance to both erosion and abrasive wear; one application showing this virtue being its use for pumps handling sea or estuarian water. It is also used in the chemical industries where corrosive liquids containing salts in suspension have to be handled; for pumps in docks and harbours. This combination of resistance to corrosive and abrasive wear has made Ni-Resist a successful material for cylinder liners. It has been established that corrosion plays an important part in cylinder wear, especially under cold engine conditions, and centrifugally cast Ni-Resist liners have given highly successful results in service.

At the end of one test, over a total of 22,500 miles made up of short journeys, the cylinder bore wear was measured on the basis of the number of miles run for each 1/1000th in. diametrical wear, giving the following figures: Plain iron 250 miles, hardened and tempered liners 1185–2140 miles, Ni-Resist liners 4000–4740 miles.

Under hot engine conditions, such as long journeys, abrasive wear appears to be the greater factor, and the relative life of cylinder materials was represented by the following percentage basis: Cast-iron cylinder block, 15; cast-iron liner, 20; nickel cast-iron block or liner, 25; heat-treated nickel cast-iron liner, 40; 5% nickel liner as cast, 100; and austenitic Ni-Resist liner, 100. These figures take no account of the variable factors such as quality of oil, driver ability, and the several other conditions which may vary so widely in actual service.

It offers resistance to growth and oxidation at high temperatures. For this quality, in addition to those of resistance to corrosion and abrasion, Ni-Resist piston rings are used in some automotive engines. For the same reason it finds a considerable application for furnace castings, particularly in connection with electric muffle-type furnaces with moving hearths, for rollers, skids, firebars and clinker dams.

It is non-magnetic and has high electrical resistance. For these reasons it is used in the electrical industries for such parts as alternator end frames and plates, switch gear and resistance grids. The fact that it can be cast in thin sections is another advantage for this work.

Ni-Resist has a high co-efficient of thermal expansion, and this also is of use in the automotive industry, the co-efficient of expansion approximating to that of the aluminium alloys used for pistons. This has made it possible to minimise piston ring groove wear by making these ring grooves of Ni-Resist, resisting wear and corrosion and maintaining a sound and complete union between piston and piston ring insert.

These notes admittedly cover only a representative selection of the applications of Ni-Resist, but serve to indicate the utility of this alloy.

Making Aluminium Alloy Castings

Various aspects of the production of aluminium alloy castings were discussed. The major difficulties generally encountered were presented in a paper by M. P. Perret, who gave recommendations for these faults. Two of the difficulties encountered are cavitations and oxide formation. The former can be prevented by keeping the runners full of metal from the commencement of pouring, by using small runners, and by forming reservoirs at the top of the moulds.

M. Perret contends that the prevention of oxidation is dependent upon the speed of pouring, apart from the placing of gates and runners, keeping this speed below that limit above which oxidation will take place through the contact with air following the breaking of the initial protective skin of the metal. He recommends that sections of gates should be considerably larger than the runners. To ensure good distribution of metal and of heat throughout the mould, it is better to use rectangular gates. Little reference was made to pouring temperature, although it is generally recognised that this factor has an important influence on the problems associated with aluminium alloy castings. A low temperature consistent with the complete filling of a mould reduces the difficulties, other things being equal.

Another paper dealt with the influence of cooling conditions on aluminium alloy castings. Dr. R. Trumann referred to the complexities of shape of many aluminium castings, involved irregular conditions in the solidifying stage, so that the density and structure vary in different parts of the same casting. For any given alloy any change in the speed of cooling means modification in the structure and, more often, in the resulting mechanical properties.

The author compared the difference in mechanical properties in castings produced in sand and from die casting, using the same alloy. Several other examples of sand and die castings were used to show the influence of conditions of solidification. The effect of coarser grain structure which resulted from slow cooling should not be exaggerated, he stated, for this factor does not have an unfavourable effect on the mechanical characteristics in that this is proportionate to the separation and agglomeration of the constituents of the alloy, the crystallisation of which has taken place independently.

These phenomena are clearly explained by examination of an alloy of Al-Cu-Mg, heat-treated.

On the other hand, it should not be forgotten that coarse grain structure is unfavourable from the point of view of the limit of proportionality, for fatigue breakages are intra-crystalline. However, tests made so far have not yet proved this.

In all cases, coarse grain structure should be avoided. One means to this end being by the addition of titanium and cerium. Certain alloys of Al-Mg-Zn_2 have proved decidedly useful in this respect.

From the constructive point of view, and from that of consideration of pouring of a mould (this referring to sand moulds) for a product with sharp angles, the author stressed the importance of avoiding acute corners in the gates of the mould, pointing out the disadvantages of such sharp corners and of excessive dimensions for the passages, at the same time mentioning the advantage of adopting some means of facilitating cooling.

Besides the study of the influence of speed of cooling of the molten metal, that is to say, the speed of solidification, it has been shown that it is also well worth while studying the speed of cooling of the metal in the solid state. Interest has been devoted to mass production castings to ascertain those factors appertaining to the best methods of forming gates and runners besides consideration of the period needed for cooling.

The author adds that the nature of the alloy plays a major part in determination of these factors.

Swedish Steel-making

THE high quality of Swedish steel is largely due to that country's ore and charcoal resources. Sweden has a wide range of ores, of compositions ranging from the high phosphorous ore of Kiruna (Lapland) to the ore of a small mine near Sandviken which contains no phosphorus at all. Most of the Kiruna ores, however, are exported and Swedish steel is made from the low phosphorous ores of Central Sweden.

At the steel works in the town of Sandviken a mixture of 32 ores is used, the ores being ground up and then mixed. Charcoal is used only in a few places. At the Sandvik works the charcoal is stored in a shed over 800 yards long, as it is only brought out of the woods during the winter. The ground-up ore is mixed with powdered charcoal, burned to a clinker, then mixed with block charcoal and limestone for delivery to the two furnaces, each of which has a weekly output of 300 tons.

Swedish steel produced here is used for watch springs, band saws, razor blades, hot-rolled tubing and cold-rolled strip and conveyer belting. At Sandviken there is a continuous mill for rolling strip 200-300 mm. wide and one large rolling mill for 800 mm. conveyer belting reducing from 4–5 mm. down to 0·4–0·5 mm.

The Sandvik works are equipped with half-ton, two-ton and three-ton electric furnaces and a 12-ton furnace has been installed. For loading this latter furnace, the furnace body is rolled out from under the electrodes and a large steel basket which just fits inside the furnace is swung above the body and lowered. The bottom of this basket consists of flexible steel strips secured at their circumference by a manila rope. The basket enters the furnace, the rope burns through in a few seconds and the load is neatly charged. This takes about three minutes as compared with the $1\frac{1}{2}$ hours necessary for loading the old style furnace with fixed top.

Applying Atomic and Kinetic Theory in a Quantitative Manner to Metallurgical Problems

The atomic and kinetic theory is discussed with a view to its use as a basis in the solution of metallurgical problems.

IT is well known that heat-treatment of alloys causes a transformation in the atomic arrangement of the different metals in that alloy, and that this is associated with anomalies in specific heat and electrical resistance. This transformation is discussed by Dr. E. J. Williams,* in which he considers the possibility of applying atomic and kinetic theory in a quantitative manner to metallurgical problems.

Analysis has shown that the atoms of the different elements in an alloy tend to arrange themselves in an orderly way at low temperatures, atoms of one kind being interspersed with those of another as far as possible. At high temperatures, however, there is a strong tendency for this order to disappear and various kinds of atoms may become distributed more at random, as though there were no difference between them.

Some of the difficulties which come within the scope of the quantum-mechanical theory of metals and metallic conduction, such as the dependence of electrical resistance on the degree of order and the absolute magnitude of the ordering energy, which depends upon the mutual energy of different atoms in the alloy, have yet to be solved; although some good work has been done in regard to the dynamical problems of the approach to equilibrium, there are still a number of obscure points to investigate, such as the relation of the rate of change of atomic arrangement to the rate of inter-metallic diffusion.

The basic principles, clearly stated by Dr. Williams, are: In a solid the points representing the mean positions of the atom are regularly arranged in space. They form a lattice which conforms to some simple geometrical pattern. If the solid is a chemical compound then in addition to this regularity in the spatial distribution of the position of the atoms, or what may be called the "atomic sites," there is a regularity in the way in which these sites are occupied by the different kinds of atoms. This order is such that if, for instance, we proceed along a line of lattice points the atoms of different kinds recur at regular intervals. This necessitates the existence of a simple ratio between the numbers of the different kinds of atoms present . . . the cohesive forces keeping the substance together are forces of attraction between one kind of atom and another.

An orderly arrangement such that certain atoms are next to each other in the lattice is in fact essential to the very existence of the substance . . . In sodium chloride the atomic sites form a simple cubic lattice. The binding is due to the attraction between the positively charged sodium atoms and the negatively charged chlorine atoms. This ensures an orderly arrangement of the atoms such that along the continuation of a line joining one atomic site to the one nearest to it, sodium and chlorine atoms occupy alternate places.

An alloy differs from a chemical compound in that the atoms of the different metals constituting it are not necessarily present in a simple numerical ratio—the ratio may have a continuous range of values—nor does the orderly arrangement of the different atoms amongst the atomic sites always exist . . The general explanation is that, in contrast with a chemical compound, the cohesive forces in an alloy are forces of attraction between the ionised atoms on the one hand and the free electrons resulting from their ionisation on the other. The atoms of different kinds play the same role—they provide free electrons and are then attracted by them. Atoms of one kind may provide a different number of free electrons per atom than the other kinds of atoms present. Besides leaving the different kinds of atoms with different charges this would also make the density of the free electrons depend very much on the atomic ratio. Even if the degree of ionisation is the same, the outer electronic structure of the different kinds of atoms will differ to some extent; giving them, in effect, a different size. It is these quantitative differences that limit the range of possible values of the atomic ratio, and which tend to make the different kinds of atoms in an alloy distribute themselves in an orderly fashion on the lattice of atomic sites. The important point is that these differences are not what is responsible for the existence of the alloy, and the ordering forces to which they give rise are weak in comparison with those in a chemical compound.

When the atomic ratio in an alloy is incommensurate then evidently an absolutely regular distribution of the atoms amongst the atomic sites is impossible . . , even when the ratio is simple such regularity does not necessarily exist. An iron-aluminium alloy with the simple composition Fe_3Al is an example. At room temperature (if in equilibrium) this alloy is ordered. Every fourth atom along a diagonal of the cubic structure is aluminium, the sequence being AlFeFeFeAlFeFeFeAlFeFeFe. At high temperatures this regularity breaks down, some of the aluminium atoms leaving their positions of "order" to replace some of the iron atoms in the 3rd, 7th, 11th, etc. positions along this line.

Resistance measurements can be used to show that ordering of the atoms takes place at the same temperature as that at which electrical resistance drops, there is a critical temperature at which ordering suddenly starts when the alloy is being cooled, this also coinciding with a discontinuation of the specific heat of the alloy, showing that these are the results of a disorder-order transformation in the alloy.

It is noted that as an alloy is cooled the ordering forces fail to set up any degree of order until the critical point is reached, and this particular temperature is sharply defined.

The degree of lag in the rate of order-disorder transformation may vary from a fraction of a second to several hours, the existence of this lag or "time of relaxation" arising from the finite rate at which the atoms of the alloy change places on the lattice, this being the essential mechanism of the transfornation, and also responsible for certain types of inter-metallic diffusion.

The author points out that when an atomic interchange is taking place the atoms concerned are at that instant not situated at the regular lattice points, there is a kind of local breakdown of crystal structure and the fraction of atoms in the alloy which at any instant are taking part in these interchanges is negligible, so that the structure is not seriously threatened by these movements even at temperatures close to melting point.

The ordering force in an alloy may be attributed to the affinity between unlike atoms being greater than that between like atoms.

Among the problems connected with the order-disorder transformation that have yet to be solved is the behaviour of alloys whose composition departs from a simple atomic ratio, with regard to the dependence of the critical temperature on the composition and the possible separation into two phases during cooling; and a theory is needed based on some simple and natural assumption regarding the forces between individual atoms and, to a minor degree, the dependence of the entropy of atomic vibration on the degree of order.

* Science Progress, XXXII, 125. 15-28.

Measuring the Thickness of Electrodeposits

Several methods have been devised for measuring the thickness of deposits. in this article attention is directed more especially to the B. N. F. jet test.

INVESTIGATION has shown that bright chromium, as deposited commercially, has a thickness that is generally a matter of a few hundred thousandths of an inch only, and this very thin coating is decidedly porous and offers little real protection to the underlying material. It was evident that an underlay of nickel is necessary to prevent corrosive agents from attacking the base metal after penetrating the pores of the chromium plating, and further investigation established that the minimum thickness of nickel should be 0·0005 in. for indoor and 0·001 in. for outdoor exposure.

A given amount of current should deposit a definite quantity of nickel, and in theory it should be possible to control the thickness by current density and duration of treatment. It is found, however, that articles of uneven shape receive a thicker deposit on those parts which are prominent, whilst poor electrical contact both in racking the parts and at the cathode bar produce uneven distribution of current. The thickness loss due to polishing is another variable factor.

Of the several methods which have been devised for measuring the thickness of nickel deposits, the simplest appears to be the B.N.F. jet test. Other methods include dissolving the nickel off a given area by a suitable reagent, then determining the amount of nickel present in the solution so formed. This gives an average figure only. Another method depends upon the fact that a nickel anode only becomes passive in sodium cyanide solution when the current density exceeds a certain level, whilst an iron or steel anode becomes passive in such a solution at a considerably lower current density. The difference in weight of a nickel specimen is ascertained after variation of current, using the plated article as the anode and a steel or other suitable part as the cathode, in a solution of 200 grammes of sodium cyanide per litre of water.

One ingenious method involves cutting through the coating on a plane surface with a grinding wheel of known radius, or on a curved surface with a fine file. In both cases the thickness T is calculated from C, the width, or chord, of the cut, and R, the radius of the wheel or curved surface, by the equation $T = \frac{C^2}{8R}$. This has been found to be sufficiently accurate when the thickness of the deposit is small compared to the radius of the wheel. A precision surface grinder has been found very convenient for testing coating on nearly flat surfaces, using a 6·8 in. diameter grinding wheel with face width of 0·15 to 0·5 in. at a speed of about 3,000 r.p.m.

Microscopic examination involves the preparation of a micro section and the use of a special measuring microscope. The Bausch and Lomb Optical Co. have developed an electroplaters' microscope fitted with a Filar micrometer eyepiece reading to 0·00001 in. thickness of deposit. More accurate determination can be made if etching is used, although specimens can be polished, if desired, on a suitable cloth-covered wheel, using levigated alumina as an abrasive.

B.N.F. Jet Test

In the B.N.F. jet test, devised by the Research Department Woolwich, at the instigation of The British Non-Ferrous Metals Research Association, a stream of reagent is allowed to impinge on the surface, thus providing a much faster rate of penetration than is the case with drop tests obviously of practical importance in the case of a resistant metal like nickel.

The surface to be tested must be free from grease and chromium coating. The latter can be readily dissolved off in hydrochloric acid containing 2 per cent. of dissolved antimony oxide to accelerate the solution process and prevent attack on the underlying nickel or steel. Degreasing can be effected by rubbing the surface with a damp swab of cloth or cotton wool sprinkled with finely powdered magnesium oxide, which is then washed off with water. The article is next dried by means of greaseless absorbent paper or cloth, or rinsed with acetone and dried in the air.

The article to be tested should be clamped about ¼ in. beneath the jet and at an angle of about 45 degrees to the horizontal. The stream of corroding solution and a stop-watch are started simultaneously and are allowed to proceed for 5 to 10 seconds. They are then stopped and the spot is examined. This process is repeated without moving the test-piece until the first sign of penetration is seen below the jet. The time required for penetration of 0·0001 in. of the coating at the temperature of testing is read from the appropriate curve (see Fig. 1), from which the thickness of the coating tested can be found by simple proportion from the time taken in the test.

The end-point cannot readily be seen whilst the liquid is running on the surface. If the thickness is approximately known it is advisable to run the solution without interruption for a time nearly equivalent to the thickness. The test should then be finished with short periods of flow of about 2 seconds each to enable the total period of penetration to be accurately timed. The corroding solution recommended for nickel has the following composition :—

SOLUTION A.

Ferric chloride	150 grms. per litre.
Copper sulphate crystals	100 grms. ,,
Glacial acetic acid	250 cc. ,,

The end-point effects with different base metals for nickel coatings are given in Table I.

TABLE I.

END-POINT DETECTION—NICKEL COATINGS.

Basis Metal.	Effect at End-point.
Steel	Coppered spot due to replacement deposit of copper; spot not formed until few seconds after flow stopped because copper is soluble in excess of solution.
Copper	Copper spot.
Brass	Brownish-yellow spot; the basis brass is somewhat discoloured.
Aluminium	Black spot.
Zinc-base die casting	Black spot.

In the case of composite deposits of nickel and copper the end-point of a copper coating on nickel is marked by a white spot and on steel the replacement deposit of copper resembles the surrounding copper coating and masks the end-point. If, however, solution B is used the respective end-point effects for copper coatings on nickel and steel are white and black spots respectively.

SOLUTION B.

Ferric chloride	150 grms. per litre.
Antimony oxide	20 grms. ,,
Hydrochloric acid (1·16 sp. gr.)..	200 cc. ,,
Glacial acetic acid	250 cc. ,,

The effect of the actual temperature at which the test is carried out is fairly considerable and this has been allowed for in Fig. 1.

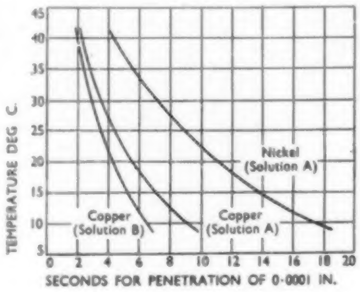


Fig. 1 Effect of temperature on penetration.

Whilst the rate of attack of the corroding solution has been found to be normal in the case of bright deposits obtained from the Weisberg and Stoddard bath, it is 1·8 times faster for the deposit obtained from the Schlötter bath. The test is non-destructive as the components can stripped and replated. It also has the advantage that it can be carried out rapidly in that perforation of the coating usually takes from one to two minutes and it is both applicable to flat and curved surfaces, the accuracy being within 15 per cent. Moreover, the apparatus itself is simple and portable.

Anodic Treatment of "Hiduminium" Alloys*

MOST aluminium-base alloys, including "Hiduminium," acquire a protective oxide film upon exposure to the atmosphere, and this film can be increased from its normal thickness of 0·0002 mm. to a maximum of approximately 0·02 mm. by one of the several electrolytic anodic oxidising treatments. The basis of this treatment is immersion in a cell, containing a suitable electrolyte, using the aluminium alloy part as the anode and oxidising the alloy surface by passing electric current through the cell. The two most widely-used processes are the Bengough and the Alumilite.

The Bengough process is used mainly for anodic treatment of alloys of the Duralumin type, using a 3% solution of chromic acid in distilled water at 40±4° C. Generally, the operation is commenced by raising the voltage from 0 to 40 over a period of fifteen minutes, maintaining the votage for 35 minutes and then raising it during 5 minutes to 50 volts, it being retained at 50 volts for the final 5 minutes. Direct current is used, with anave rage consumption of 2·8 to 3·5 amps. per square foot of surface.

By use of the Alumilite process, varying thicknesses of film can be attained, and the degree of hardness is also controllable. This is achieved by variation of the concentration of the sulphuric acid electrolyte between 7% and 35%. Treatment is carried out with the bath at 18±2° C., using direct current with voltages of 10–20, and entailing consumption of approx. 10–20 amps. per square foot of work surface.

As the oxide films thus produced have a cellular structure sub-microscopic in nature, they should be sealed against corrosion by an impregnating material. This sealing is accomplished by the application of lanoline or similar material as a solution in petrol in the Bengough process, and in the Alumilite process the sealing is carried out by immersion in boiling water containing an insoluble in organic salt, such as barium sulphate, in suspension, or in an aqeuous solution of boric acid. By adjustment of solutions and temperatures in the Alumilite process it is possible to give controlled conditions of the 25% sub-microscopic porosity which is claimed to afford full protection against surface stress.

The oxide films possess high electrical resistance; Bengough films will withstand 100 volts and Alumilite films 500 volts. Specially produced Alumilite films have shown resistance exceeding 3000 volts. The hardness and smooth surface of the films enable the process to be adopted in the anodising of aluminium alloy pistons for internal combustion engines, increasing wear resistance, whilst the porosity of the film surface forms an excellent surface for oil retention.

Another advantage is that the unsealed porous films provide a very good base for paints, with remarkably strong adhesion between paint and metal.

The anodic films are normally colourless and as they have a very high property of absorption can be immersed in water solutions containing dyes, providing a variety of brilliant colours readily absorbed by the films. The dye penetrates the coating, gives deep rich hues and an underlying metallic sheen; sealing treatment can be given after dyeing.

* "Data Sheet" No. 38, published by High Duty Alloys Ltd., Slough.

Ontario Nickel-Copper Production Increases

CRUDE ore treated at Ontario nickel-copper smelters and concentrators during the first three months of 1937 totalled 1,469,377 tons, as compared with 1,044,552 tons a year ago. During the period 1,117,617 tons of ore were concentrated, with a recovery of 495,981 tons of concentrates. Ore and concentrates charged to the smelters totalled 850,590 tons, including 351,760 tons of crude ore and 498,830 tons of concentrates.

The International Nickel Company operated the Frood and Creighton mines throughout the period and re-opened the Garson and Levack mines. These, with the Falconbridge mine, owned and operated by Falconbridge Nickel Mines, Ltd., made a total of five active mines. During the first three months, smelting units were active at Copper Cliff, Coniston and Falconbridge, and refineries at Port Colborne and Copper Cliff. The Cuniptau, which closed in October of last year, was reported as having contracted with the Van Nickel Mines of the Sudbury area for a supply of 30,000 tons of ore to be delivered during a period of fifteen months.

Refined copper production (blister) rose during the quarter from 69,151,163 lbs. in 1936 to 75,052,040 lbs this year; whilst refined nickel produced is up from 25,818,416 lbs. to 33,768,825 lbs. Matte exported declined during the quarter from 14,505 tons to 12,974 tons, the nickel content being down from 18,583,093 lbs. to 16,144,103 lbs.; whilst the copper content is up slightly from 3,723,427 lbs. to 3,981,283 lbs.

To Increase Output of Rare Metals in U.S.S.R.

A FIVEFOLD increase in the output of rare metals is planned by the Soviet Rare Metals Industry at the end of the Third Five-Year Plan (in 1942). By that time, too, ore concentration processes and mining operations will be completely mechanised, and production costs reduced by 40 per cent. During the Five-Year Plan, it is hoped to meet the full requirements of the home market in basic rare metals, such as tungsten, molybdenum and mercury. Among the new metals to be mined are niobium, zirconium and rare elements like indium, germanium, etc.

The Council of the Royal Aeronautical Society have elected the following for the year, October, 1937—September, 1938:—President, Mr. H. E. Wimperis, C.B., C.B.E., M.A., M.I.E.E., F.R.Ae.S.; Vice-Presidents, Mr. F. Handley Page, C.B.E., F.R.Ae.S.; Mr. A. H. R. Fedden, M.B.E., M.I.A.E., M.S.A.E., F.R.Ae.S.; Mr. A. H. Hall, C.B., C.B.E., M.Inst.C.E., M.I.Mech.E., F.R.Ae.S.; and Mr. D. R. Pye, C.B., M.A., M.I.Mech.E., F.R.Ae.S.

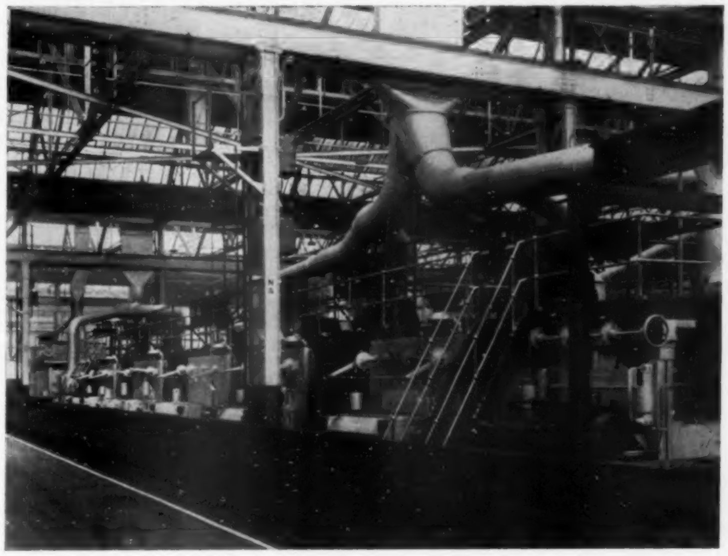
Recent Developments in Materials, Tools and Equipment

Automobile Spring Heat-Heating Furnaces

NOT the least important part of an automobile is its springs, and the correct heat-treatment of these is very essential to ensure proper resiliency and long life. A very interesting installation of heat-treatment furnaces for this purpose is in use at the Dagenham Factory of the Ford Motor Co., Ltd., and consists of six hardening and one tempering furnace.

Four of the hardening furnaces are each capable of an output of 2,370 spring leaves per 16-hour day, and the leaves are approximately 2¼ in. wide with a varying thickness between ¼ in. and ⅜ in. The length of the leaves varies between 8¼ in. and 37 in. Each of the two other hardening furnaces has an output of 2,580 leaves per 16-hour day, and the length of the leaves varies between 28 in. and 54 in., whilst the width is 2½ in.

The heating cycle in all cases is from cold to 1,550° F. (843° C.) in 10 minutes and soak at this temperature for 6 minutes, but this cycle can be varied if desired.



A battery of seven gas-fired spring hardening furnaces installed at the Ford Motor Works.

In each of the furnaces the leaves are carried on roller chains constructed entirely of heat-resisting alloy and in such a way that the rollers are effective both when carrying the work, and on the return journey. The chains are completely enclosed in the case of the hardening furnaces and therefore little heat is lost from the conveyer during its return to the charging end. The chains travel along longitudinal skids of heat-resisting alloy and these skids are in turn supported on cross beams.

Each hardening furnace is divided into two zones, a heating zone and a soaking zone and each zone is automatically controlled with regard to temperature by means of a two-point Leeds & Northrup Potentiometer-type controller. The burner equipment is of the automatic proportioning single valve control type using air under pressure along with gas at low pressure, and the burners are arranged both above and below the leaves. This arrangement gives both rapid and uniform heating.

The products of combustion from all the burners pass to the charging end of the furnace, and thus preheat the incoming work, but in addition a metallic-type recuperator is fitted to preheat the air for combustion.

The fuel used is coke oven gas and the gas consumption in the hardening furnaces is approximately one cubic foot of gas per lb. of steel heated. This high efficiency is made possible by the use of scientifically correct burner equipment and efficient insulation of the furnace itself.

Tempering Furnace

This furnace is of somewhat unusual design and the spring leaves are heated entirely by means of circulated hot air. The whole of the output of hardened and cambered springs are passed through this furnace and uniformity of heating is most essential for this operation. The methods of carrying the leaves through the furnace is similar to that described for the hardening furnaces, except that to facilitate handling of the leaves the conveyer chains actually pass out of the furnace at the discharge end and return under the furnace.

Heating of the leaves is as previously mentioned, carried out by the use of hot air which is circulated through the furnace by means of two electrically driven fans mounted on top of the furnace. Immediately on the outlet of each of these fans is a direct-gas-fired heater wherein the air is reheated before again passing into the furnace.

One fan supplies the hot air to the heating zone of the furnace, and the other the soaking zone, and each heater is automatically controlled as to temperature by means of a Leeds & Northrup Potentiometer type controller. The hot air is distributed in the furnace through ducts down each side, and extracted through further ducts for passing back to the fan. The furnace is of suitable width to accommodate springs 54 ins. long, and capable of an output of 9,500 leaves per day of 16 hours. The gas consumption for this duty anounts to 2,000 cubic feet per hour.

The spring leaves treated in this installation pass all the rigid tests imposed by the laboratory and inspection department without difficulty and the percentage of rejects is negligible. The furnaces were designed and constructed by British Furnaces, Ltd., of Chesterfield, in collaboration with the Engineering Staff of Messrs. The Ford Motor Company, Ltd., Dagenham.

New Electric Heat-Treatment Furnace Installation

MANUFACTURERS engaged in brass drawing will know the difficulties experienced in reducing rejects to a reasonable percentage. When tools are of good design, and there are no great difficulties inherent in the article itself, rejects are generally due to faulty heat-treatment.

It is therefore of interest that two electric furnaces of the vertical type with forced-air circulation have been installed at the Royal Arsenal, Woolwich, for this class of work, and their uniformity of temperature and close control is such that there have been no rejects at all since their installation.*

These furnaces are equipped with charge progress recorders, switchgear, cooling tank and electric hoist. The two furnaces are sunk in a pit, their top-plates being 4 ft. above ground level. Accessibility of the fan motors has been considered.

* "The Wild-Barfield Heat-Treatment Journal." June, 1937.

Two forced-air circulation electric furnaces installed at the Royal Arsenal Woolwich

Normal operating temperature is 620° C. The parts to be treated are supported in baskets of aluminised steel, nests of trays being used to provide for the variation in size of the parts for treatment. The general construction is similar to other Wild-Barfield furnaces, but the door gear and fan-drive have been modified. The centrifugal-type fan is of welded construction mounted on a heat-resisting shaft supported by roller bearings after it has passed down and through the insulation at the base of the furnace, and is driven by a 5-h.p. Star-Delta starting squirrel cage motor.

Grooved refractory element formers are mounted on pins and wound with induction-melted 80/20 nickel-chromium wire. The lead outs are brought through the insulation to busbar chambers on the outside of the case, just above ground level. A wire mesh grid prevents any articles from falling upon the elements.

Although the door weighs just over one ton, it is very light to operate. Strong channel framework at the back of the furnace carries a cantilever arm and a 10-leaf cantilever spring which, with the interposition of a roller and roller-plate, ensure light operation for the motions of lifting and swinging the door to one side. A switch on the door supports automatically cuts out the heating elements and fan motor drive when the door is opened.

Each furnace is rated at 120 kWs., giving a heating-up time, when empty, of approximately one hour from cold to 620° C. The weight of the charge varies according to the size of the parts to be trated, but for a charge of 1,750 lbs. nett weight the following table exemplifies a typical working cycle :

Heating charge to 620° C. in hot furnace	1·26 hours.
Soaking period	0·25 ,,
Removing charge, and inserting fresh one	0·10 ,,
Total	1·61 ,,

Charge progress recorders are provided for each furnace, mounted in a pedestal-type case situated next to the switch panel adjacent to the wall. The instrument is a millivoltmeter pattern automatic temperature controller, with the moving-coil system connected alternatively to two thermo-couples, one at the top of the furnace, and the other in the throat just above the fan. A permanent record is given of the treatment given to each batch of work, which can be checked in the event of faults occurring during subsequent drawing operations. A time-switch is incorporated, so that the furnace is switched on and attains working temperature when work is commenced.

A special cooling tank saves valuable time. This has a swing-lid and centrifugal blower. The charge can be cooled to 200° C. in a very short time, and is then brought to room temperature by cold water spray from nozzles inside the top of the tank.

An electrically-operated hoist is used for both lifting and traversing, the runway being above the full length of the furnaces and cooling tank. Lifting speed is 15 ft. per min., and traversing speed 100 ft. per min.

G.E.C. Electric Furnaces

As a result of the extended use of electricity for industrial heating purposes, there has been an increasing demand for the electric furnaces and other heating equipment that have been made for many years by the General Electric Co., Ltd., at Magnet Works, Birmingham. It has, therefore, been found necessary to give more space to this important part of the G.E.C. manufacturing organisation, and the electric furnace sectionof the works has been transferred in its entirety to the Company's Fraser & Chalmers Engineering Works, Erith, Kent.

Expansion at Erith was rendered possible by the recent acquisition of an adjoining factory, so that extensive furnace manufacturing facilities are available, and an entirely new shop has been built for erection purposes. The fifty years' experience of Fraser & Chalmers, covering turbines, winding engines, oil engines, conveyers, mining machinery (including smelting furnaces) and other types of mechanical plant, will be of great value, not only in the construction of the electric furnaces themselves and the associated conveyers and charging gear, but also in the solution of the metallurgical problems encountered in their design and application.

G.E.C. electric furnaces are being used to-day in a wide range of industries where absolute accuracy and precision of temperature control are essential. Examples are the annealing, hardening, tempering, forging and heat-treatment of iron and steel and the melting, annealing, hardening, tempering, forging and heat treatment of copper, brass, aluminium, gold, silver and other non-ferrous metals and alloys. Other furnaces are designed and built for such diverse purposes as vitreous enamelling of cast iron and sheet metal, drying cores and moulds, baking enamels and japans on sheet metal, drying paints and varnishes, armatures and coils, etc.

New Furnace erection shop at the G.E.C.'s Fraser & Chalmers Engineering Works, Erith

The Ural-Kuznetsk Combine

By A SPECIAL CORRESPONDENT

In this article the author reviews briefly the contribution of the Ural-Kuznetsk Combine to the industrial development of the U.S.S.R., and indicates the remarkable achievements made in the last few years in the production of ferrous and non-ferrous metals from available raw materials.

THE Ural-Kuznetsk Combine is a group of inter-related enterprises based on the iron ores of the Urals and coal from the Kuznetsk Basin. It has been designed with a view to the more economical and rational utilisation of the raw materials in the vicinity, as well as the transport facilities and the power supply. The main territory of the Ural-Kuznetsk Combine includes the Urals (Cheliabinsk and Sverdlovsk Regions), the Orsk-Khalilovo District, the Middle Volga Region, the West Siberian Territory (chiefly the Kuznetsk District), Kazakhstan, with its three rich mineral-bearing districts of Karaganda, Ridder, and Counrad.

The bases for the raw material of the Ural-Kuznetsk Combine are the following :—

Iron Ore.—There are now six iron ore districts of industrial importance in the Urals—namely, Nadezhdinsk, Tagilo-Kushvin, Alapayevsk, Bakal, Magnitogorsk, and Komarovo-Zigazinsk. Of the ascertained supplies, 475 million tons represent those of the Magnitnaya Mountain. In addition to the deposits referred to, the Urals also contain large supplies of titano-magnetite ore (more than a hundred million tons). The latter ores are of particular importance, containing as they do the rare elements of vanadium and titanium used in the production of quality alloy steels.

The deposits of polymetallic ores at Khalilovo are a continuation of the ore deposits of the Southern Urals. These deposits occupy an area of 2,000 sq. km., but only 100 sq. km. have so far been prospected. The Khalilovo ore deposits are estimated at 400 million tons. Besides iron, the Khalilovo ores contain such valuable metals as nickel and chromium.

As a result of extensive geological prospecting carried out in Siberia, a number of first-class deposits of iron ore have been discovered in the Gorno-Shorisk, Minusinsk, Abakan and other districts. The iron ore supplies of West Siberia alone are now estimated to amount to 414 million tons. When the Kuznetsk blast-furnace was first started, the idea was that it would operate almost entirely on Magnitogorsk ores, brought from a distance of 2,300 km. away. In 1936, however, more than one quarter of the blast-furnace production was supplied by local ores.

The huge supplies of iron ore in the Urals and in Siberia make it possible to extend the manufacture of iron and steel in the system of the Ural-Kuznetsk Combine on a vast scale. The metallurgical industry in the East of the Union has been developed to some extent by the reconstruction and enlargement of old works in the Urals, but to a still greater extent by the building of new ones.

Of the old steel plants in the Urals, reconstructed in recent years, mention should be made of (1) the Kabakov (formerly Nadezhdinsk) Works, which has been converted into a large plant for the production of quality and super-quality metals. (2) The Zlatoust Works, also a quality metallurgical works which since its reconstruction, has become, together with the Kabakov Works, one of the chief suppliers of metal for the motor-tractor and machine-tool industries. (3) The Chusovaya Works, which has perfected in its blast-furnaces the production of vanadium pig iron from titano-magnetite ores, and is now producing this metal on an industrial scale and converting it by various processes (open-hearth slag, chemical and electric furnace treatment) into ferro-vanadium. In 1935, the Chusovaya Works produced 300 tons of ferro-vanadium, and there is every reason to anticipate that in 1937 the U.S.S.R. will have no further need to import this valuable alloy. In 1937, the first few tons of another alloy, ferro-titanium, were produced at the Chusovaya Works, this being one of the best de-oxidisers and an indispensable constituent in the manufacture of important grades of alloy steels. (4) The Verkhnaya Iset Works, which has now become one of the chief producers of dynamo and transformer iron for use in electrical engineering. Besides these, there are also the Nizhnaya Salda, Beloretsk, and other steel works.

The scale on which reconstruction work has been carried out may be judged from the fact that, for example, the reconstruction of the Zlatoust Works cost several times as much money as was expended on the original plant. The new plant installed at the works includes a blooming mill, a large preparatory rolling mill, a number of new open-hearth furnaces, five large electric furnaces, including two 15-ton furnaces, etc. As a result, the output of quality rolled metal at the Zlatoust Works during the last few years has increased several times over. At the Chusovaya Works, in addition to the special shops and plant for the production of ferro-vanadium, a large press has been installed, as well as a large specialised rolling mill for producing steel springs of different shapes for the motor and rolling-stock industries.

But despite the immensity of the scale of reconstruction carried out in connection with the Ural-Kuznetsk Combine, it is as nothing compared to the vastness of the new building. One of the largest enterprises to be put up is the Magnitogorsk Metallurgical Combine. The plan for the Magnitogorsk Combine, as finally approved, includes the following :—A mine, capable of producing 12,000,000 tons of iron ore a year ; two ore-washing plants and a concentrating mill ; an agglomeration factory with 10 conveyer belts, capable of agglomerating 5,000,000 tons a year ; crushing and magnetic concentration plants, with an output of 3,000,000 tons of crushed, concentrated, and sorted ores a year ; a huge coke and chemical works, comprising ten batteries, each with 65 to 69 furnaces, producing 4,200,000 tons of coke a year, and large quantities of valuable chemicals ; eight large, completely mechanised, blast-furnaces, with a volume of 1,180 cubic metres each, and an output of 4,300,000 tons of pig iron a year ; twenty-nine 100-ton open-hearth furnaces with a capacity of 4,800,000 tons of steel a year ; and three blooming mills, three roughing and six finishing mills to produce 1,200,000 tons of rails and 2,500,000 tons of various rolled goods a year.

Also forming part of the Magnitogorsk Combine are an electric power station of 223,000 kw. capacity, a large factory for the manufacture of refractories, mechanical and casting shops, shops for manufacturing railway fish-plates, etc.

At the beginning of 1937 the following units of the Magnitogorsk Combine were already in operation : Four blast-furnaces (the first was opened in 1933), twelve open-hearth furnaces (the first was opened in July, 1933), one blooming mill (put into operation in August, 1933), two preparatory and five finishing rolling mills, four coke batteries, an electric power station, a mine, etc. In 1936 the Magnitogorsk plants produced 1,557,000 tons of pig iron, 1,164,000 tons of steel ingots, 947,000 tons of rolled metal.

Next in order of importance are the Kuznetsk metal-

lurgical plants in Siberia, which are now complete. They were the first metallurgical plants to be put up in Siberia. The plant comprises mines, lime quarries, a crushing plant, and an agglomerating plant with three conveyers; five coke batteries with 55 ovens each, with an annual output of 1,800,000 tons of blast-furnace coke; a large chemical works; two blast-furnaces, with a volume of 821 cubic metres each, and two with a volume of 1,163 cubic metres each, capacity 1,740,000 tons of pig iron a year; twelve 150-ton and one 300-ton open-hearth furnaces, with an aggregate capacity of 2,150,000 tons of steel a year; a rolling shop with two blooming mills, a rail rolling mill, and a medium sheet rolling mill, with a total capacity of 1,700,000 tons of rolled goods a year; a central electric heating station, with a capacity of 140,000 kw., and a number of auxiliary shops.

Besides these two large steel plants, the first units of the Novo-Tagil Metallurgical Combine (in the Urals) are being put into operation this year. These will work on Tagil iron ore, and consist of a blast-furnace, two open-hearth furnaces, and a mill for rolling rails. When completed, the Novo-Tagil Combine will comprise four large blast-furnaces, two open-hearth furnaces, a blooming mill, and a number of large rolling mills. The Novo-Tagil plants will be of greater capacity than the Kuznetsk plants.

Of the enterprises in the Ural-Kuznetsk Combine built since 1930, two others are worthy of mention. One of these is the Cheliabinsk Ferro-Alloy Works, which produces in its eleven electric furnaces many different kinds of valuable alloys, such as ferro-silicon, ferro-chrome, and ferro-tungsten. In 1936 the Cheliabinsk Works turned out 35,000 tons of ferro-alloys, not hitherto manufactured in the U.S.S.R. The other enterprise is the Pervouralsk Tube Works, which produces iron tubes for locomotive building, motor and tractor manufacture, and other purposes.

As a result of all this new construction, the output of iron and steel in the Soviet East has increased rapidly. In 1936, the output of pig iron in the East, as compared with 1930, rose by 340%, of steel ingots by 390%, and steel sections by 400%.

Non-Ferrous Metal Production

The Soviet non-ferrous metal industry is mainly concentrated in the East, owing to the large deposits of all kinds of non-ferrous metals in the Urals, Siberia, Kazakhstan and the Altai. With the exception of tin, nearly all metals are found in these regions in large quantities. The territory of the Ural-Kuznetsk Combine contains 90% of the Union's resources in copper, 70% of the resources in zinc, and 75% of the resources in lead. The territory also contains aluminium, nickel, and magnesium ores. Kazakhstan is particularly rich in metals, with its big deposits at Jezkazgan, Ridder, and Chimkent.

The non-ferrous metal enterprises included in the Ural-Kuznetsk Combine comprise the Krasnouralsk, Kalatinsk, Karabash copper smelting works, the Pribalkhash copper combine, the Kyshtym and Pyshmin electrolytic works in the Urals, the Jezkazgan copper-smelting works, the Ridder and Chimkent lead works, the Belov zinc works, the Ufalei nickel works, etc.

The expansion of the metallurgical industries has necessitated the building of a number of electric power stations in the Urals and Siberia. In addition to the Magnitogorsk station are the Kemerovo station, with a capacity of 48,000 kw.; the Kuznetsk station, with a capacity of 109,000 kw.; the Kizel station of 81,000 kw. capacity; the Cheliabinsk station, with a capacity of 150,000 kw.; and the Berezniki station of 105,500 kw. capacity. In 1936 the district electric power stations of the Ural-Kuznetsk Combine produced 4,250 million kilowatt-hours of electrical energy, about 50% more than was produced in 1935.

In conclusion, mention must be made of the close interrelation of the different industries included in the Ural-Kuznetsk system, and the way in which industries are coupled for the purposes of rational exploitation. This coupling of industries on a large scale, linked up with common power supplies and transport facilities, has proved an excellent solution on the most rational lines of the problem of industrial development in these vast regions of the Union.

Canning Practice and Control

A comprehensive book on modern canning practice contains sections of interest to metal producers and users, in regard to metals used and the processes of making cans, and washing, filling, air-exhausting sterilising and cooling plant. Its aim is to collate those items of information the canner needs if he is to put on the market a properly processed foodstuff. The definition of canned food that has been adopted is that "foodstuff hermetically sealed and processed in a metal container," which includes fruits, fish, vegetables, meats, but not powders and other dry solids such as milk, biscuits, cocoa, coffee, etc., sealed in tinplate containers.

The most common material for the cans is tinplate, the grade most generally used in Great Britain being 28–32 B.G.b having a tin coating of between 1·5 and 3 lb. per basis box of 112 sheets, each 20 × 14 ins. The authors describe the rolling, pickling and annealing processes; the tinning apparatus and the types of annealed plate. An interesting point is that electro-deposition of tin on top of the hot-dipped tin coating has been studied, largely with a view to reducing porosity.

The two types of annealed plate on the market are the charcoal and coke types. The meat canner seems to prefer the charcoal annealed plate, but, for canning of acid foodstuffs needing maximum resistance to corrosion, the steel should have a low sulphur content, and the copper content should not be less than twice that of the sulphur.

Interesting figures and general notes on lacquering are given, whilst details of mechanical filling machines, thermocouples for the sterilising retorts, the various types of retort—divided broadly into continuous and intermittent types—and laboratory equipment are of more specific interest. Illustrations showing results of gelatine-ferricyanide tests applied to tinplate, and the method advocated for determining the amount of lead present in solder submitted will also be of interest.

Much of purely academic interest, particularly in regard to the chemistry of foodstuffs, in general, has been deliberately omitted. It has been the object of the authors to prepare a bench book, rather than to compile a treatise, but many readers will consider the interpretation of the former term rather liberal in certain directions, particularly in the chapters dealing with the canning and preliminary equipment, the canning laboratory and its work, and cultural notes of the principal food-spoiling organisms; but these add interest to a complicated subject.

The authors have stressed the principles, and only amplified in detail where detail is of special value in giving the reader a proper appreciation of the subject. On the analytical chapters the methods discussed apply only to those substances likely to be handled in the canning factory, and in many cases only one method is given for a particular determination.

Other chapters deal with mycology, and although the authors have given adequate detail, they have wisely made no attempt to include the morphological characteristics of all the bacteria that might be found in canning practice. It is a very informative book, well written and illustrated, and will become a standard work of reference for the canners assisting him to market properly processed foodstuffs.

By Osman Jones, F.I.C., and T. W. Jones, B.Sc.(Lond.). Chapman and Hall, Ltd., 11, Henrietta Street, London, W.C. 2. 25s. net.

Development of Light Alloy Bearings

Much attention has recently been given to the development of light alloy bearings, and in this article progress in their use is briefly reviewed.

CONSIDERABLE development has taken place in Germany in regard to light alloy bearings, this being due in great part to the demands of aircraft engines and, in rather less degree, to the increasing power output per litre of automobile engines.[1]

The white metal alloys showed certain limits under these highly stressed conditions, and lead-bronze bearings were developed. These, however, proved to be a stage towards the introduction of light alloy bearings and the development was given impetus by the recent shortage of tin in Germany.

The first alloys were of aluminium-copper and aluminium-silicon, similar to those already being used extensively for pistons, but these were found to have definite limitations under conditions of inefficient lubrication, were sensitive to edge pressures, and involved machining with a diamond-tipped tool. Both these alloys possess hard crystals, and new alloys were considered, having a fine grained mass of several crystal types—*i.e.*, of the eutectic type. Hyper-eutectic alloys of this type were found to have a structure consisting of primary hard crystals carried in a soft eutectic ground mass, the hard crystals being coarse-grained, being controlled by additions to the alloy, by control of the solidification and by forging the cast alloy.

The alloys thus produced were tested for hardness, tensile strength, compression strength, melting-point, coefficient of expansion, and wear and bearing tests, the latter both with and without lubrication. The wear and bearing tests were usually carried out with pressures of approximately 200 kg./cm.^{2}, at speeds of 7–8 m./sec. After these laboratory tests the bearing was tested under service conditions in an engine, when it was found that some of the bearing alloys which had given excellent results in the laboratory would seize for no apparent reason even after running satisfactorily for 50 or more hours.

Later experiments showed that this seizing was probably due to the growth of the bearing alloys at elevated temperatures, or possibly to deformation of the bearing support causing temporary metal-to-metal contact between the bearing and the shaft. Oil-resisting, rubber and spring steel inserts were tried, but did not prove satisfactory over long periods of use. The tendency of light alloy bearing metals to deformation must be countered by allowing a clearance of 0·1 mm. in a 65 mm. diameter bearing, running at a speed of 7–8 m./sec. (2·3–2·62 ft. per sec. approximately).

Two alloys have been developed, known as "soft" and "hard" alloys. The first is suitable for less highly stressed bearings for pressures up to 200 kg./cm.^{2}, and the second is used in all cases where the supporting parts of the bearing have to be of the same alloy, and is specially suitable for high-speed bearings. Both can be used with either soft or hardened journals.

A review of the present position shows that light alloy bearings can be used with satisfaction for certain bearings.

The possibility of using light alloy bearing metals in the form of linings cast on sheet steel or light alloy bearing supports, as in the case of silicon alloy parts, is worth exploration, especially as very good results have been obtained with the silicon alloy bearing in automotive work.

For lightly stressed bearings, magnesium base alloys of the Elektron type have given satisfaction, but the qualifications of efficient lubrication and maintenance of temperature at or below 100° C. must be observed. Actually, experiments in aluminium-base alloys for bearing work were made before the war.[2] The one alloy which seems to have given any degree of satisfaction was a graphited (4% by volume) Al-10% Cu alloy, this proving superior to bronze bearings. Present experiments with graphited aluminium alloys are being made, these containing 3–4% Cu, 2% (max.) Fe, 3% (max.) Pb and Zn, 0·1% C, and the remainder aluminium. The structure is heterogeneous, and the graphite tends to irregular distribution.

The behaviour of light bearing metals is not only dependent upon their composition, but on the design of the bearing proper, its support, conditions of lubrication, etc. Even should seizing take place, the hardened steel journal is not likely to be damaged, as the light alloy which would adhere to the shaft can easily be removed.

Given suitable conditions, excellent results have been given by Duralumin, "Alugir" (3% Cu, 0·8% Zn, 1–1·5% Ni), "Chromet" (10% Si), and RR 56 bearings, on hardened journals.

The Q5 alloy (5% Cu, 1% metals of the iron group, 0·5% grain-refining additions, remainder Al), of the Quarzal alloys, is said to have given the best results. This alloy has a high coefficient of expansion for which allowance should be made, and diamond machining is recommended to prevent any difficulty in running-in.

A very interesting alloy is the high silicon KS 280, in which a special process is used, to cause separation of small uniformly distributed primary Si crystals, resulting in a structure which resembles closely the white metal bearing alloys. This has a 120 Brinell hardness, a comparatively low coefficient of friction, and a small coefficient of expansion of 17×10^{-6}. The alloy bearing must be used with a hardened and polished shaft, exact clearance must be maintained, and the bearing surface must be fine-machined, as no running-in is possible. The composition is Si 21–22%, Co 1·2%, Cu 1·5%, Mn 0·6%, Ni 1·5%, Mg 0·5%, remainder Al.

A more recent development is that of several alloys in which the "bearing crystals" consist of aluminides of the iron group of metals, these crystals being broken up and distributed uniformly by mechanical treatment after casting.

There is also the KS 13 alloy, with comparatively low strength and softness, Brinell hardness, in as-cast condition, 40. It is used in layers of about 1 mm. thickness on KS 280 or Duralumin supporting shells. This has given very good results in service. Composition is 6–8% Sb, remainder Al.

1 H. Wiechell. *Automobil- und Flugtechnischen Gesellschaft.* Berlin, 22/4/37.
2 R. Hinzmann. *Metallwirtschaft*, 1937, XVI, 20, 477.

Big Gold Mining Centre in Steppes of Kazakhstan

A BIG gold mining centre has been created in the heart of the Kazakh steppes, at the Maikain mine, some 65 miles from Pavlodar. Employing only 300 workers eighteen months ago, the mine now has 5,000 workers. A large settlement has sprung up in the neighbourhood with all the amenities for a social and cultural life. Both gold and silver are obtained from the brown hæmatite ore, which lies very near the surface. In addition to gold and silver are polymetallic ores, quarry-stone, limestone, fireproof clay, brown coal and coal suitable for coking. Maikain now has two small amalgam works, and another with a capacity of 1,000 tons a day is being planned. Plans are also being made to sink a big new mine, which will be entirely mechanised, and to erect an electric power station.

Weight Loss of Copper in Sodium Hydroxide Solutions at High Temperatures

TROUBLE due to corrosion and wasting away of copper ferrules used in packing locomotive boiler flues led ot experiments to determine whether this was caused by chemical action of the boiler water constituents, or stray current electrolysis, or the possible electrotechnical action produced by difference in potential of the copper and flue metal. Investigations on this subject, based upon the assumption that the trouble was due to corrosion, are discussed by A. S. Perry.* The mineral constituents present in locomotive boiler waters, generally speaking, are sodium sulphate, chloride, carbonate, and hydroxide, of which sodium hydroxide is the most active and was therefore considered first.

Tests were carried out in six boilers containing insulated copper strips immersed in distilled water and also various solutions of sodium hydroxide from 0·1 to 2·0 grammes per litre. These were maintained for 100 hours under 200 lb. sq. in. steam pressure, corresponding to a temperature of 381·8° F. The strips were then cleaned and weighed and loss in weight recorded. The results showed a loss in weight of 0·06% for the copper immersed in distilled water, and the loss increased to 0·55% in the solution of 2·0 grs. per litre sodium hydroxide ; but, for some reason unexplained, the specimens in the solution of 1·5 grs. per litre sodium hydroxide showed an abrupt drop to 0·16% loss.

The tests showed that an increasing loss in weight can be expected when copper is exposed to increasing concentrations of sodium hydroxides at high temperatures, except in the region of 1·5 grs. of sodium hydroxide per litre where there is a distinct reduction. Although the chemical action increases with increasing concentrations at elevated temperature, it remains comparatively small and not sufficient to account for the loss of copper in boiler work of locomotive type.

Thus the tests did not offer a solution of the trouble and the results obtained form a record for reference should further research be undertaken.

Aerial Ropeways

THE advantages of the aerial ropeway for the conveying coal, coke, iron ore, and other material are well known, and in this connection considerable interest attaches to a mono-cable ropeway that has been completed by the British Ropeway Engineering Co., Ltd., of London (14-18, High Holborn, W.C.1), which takes coal from the Wombwell Main colliery to the bye-product coke oven plant at the Barnsley District Coking Co., Ltd., at Barnsley, a distance of 2,500 yards (base line). In striking fashion also this ropeway crosses over one set of railway sidings, three different main lines, and four public roads, the speed of the rope being 120 yards per minute, while the duty is 55 tons of coal per hour, the coal averaging 52 lbs. per cubic foot.

In this installation there are 90 carriers attached to the travelling rope, of which at any given time 88 are on the line and two at the end stations. Each of the carriers also takes 9 cwt. of coal and is spaced at a distance on the line of 58·5 yards, while 120 loads per hour are discharged at a time interval of 29½ seconds. Also the difference in level between the terminals is 15 yards against, and the only power required is 20 h.p., for this purpose a 32 h.p. electric motor being installed.

It will be remembered the general advantages of ropeways are extremely small operating costs with minimum attendance, wide range and easy operation without regard to the nature of the country involved, whether rivers, streams, marshes, canals, railways, roads, obstacles such as refuse dumps and mountains. Thus ropeways are easily installed when no other method of transport can be used, of which the above installation is a good example, crossing all the different railways and roads already mentioned. For such conditions special protective bridges are erected, passing under the ropeway in such a manner that it is impossible for material to fall down on to the rail, road, or other area below.

Ropeways also have been constructed up to say 50 miles in length, with capacities up to 300-400 tons of material per hour, while other of the main applications include the conveying of coal and ash at power stations, and the loading of ships with coal and other material. Further examples are quarries, claypits, and sand and shingle pits, while it is not aways realised the ropeway is very valuable for iron and steel works and all kinds of industrial establishments, both for short and long distances, as well as for the public conveyance of goods in country where rail or road transport is impossible as a commercial proposition.

* A. S. Perry. *Ind. Eng Chem.*, 29. No. 6, p. 677.

Tin Consumption Analysis

WORLD production of tin in the first four months of the current year was 60,646 tons, according to the International Tin Research and Development Council's Bulletin, showing an increase of about 5,600 tons as compared with the corresponding period of 1936. The comparable statistics of consumption were 65,636 tons in 1937 against 54,691 tons in 1936. Attention is drawn to an important revision in these statistics, whereby they now include the quantities of tin smelted and consumed locally in such countries as Japan and Australia. This revision has been applied to the figures for past years as well as for the current year, so that these statistics now cover practically the whole of the world's production and consumption of tin, excluding only the quantities refined and consumed locally in China, in respect of which no information is available. Statistics for the past three years on the new basis are given as follows :—World production, 1934, 114,881 tons ; 1935, 146,819 tons ; 1936, 178,226 tons. World Consumption, 1934, 122,790 tons ; 1935, 148,713 tons ; 1936, 162,738 tons.

The increase in world consumption in the year ended April, 1937, was due principally to the U.S.A., where there was an increase of 17,800 tons over the previous year's consumption.

Apparent consumption in the United Kingdom shows a decrease of 14·7 per cent., despite increased activity in the tin consuming industries, this indicating that "invisible" stocks (in consuumers' works or at smelter) are being depleted. Consumption in Russia, at 11,155 tons, has again exceeded all previous records, being nearly 40 per cent. ahead of the figure for the previous year. Substantial increases in tin consumption are also recorded for France, 13·9 per cent. ; Japan, 25 per cent. ; Poland, 48 per cent. ; and Canada, 10 per cent.

Tin Consuming Industries

World production of tinplate increased by 24½ per cent. from 3,196,000 tons in the year ended April, 1936, to 3,976,000 tons in the year ended April, 1937, and the quantities of tin used in this industry were respectively 53,000 tons and 66,000 tons. The world output of motor vehicles in the year ended April, 1937, totalled 6,060,000 vehicles, against 5,251,000 vehicles in the preceding year. Approximately 13,500 tons of tin were used in this industry in the year ended April, 1937.

Soviet Diesel Engine with Gas Generator

AN experimental Diesel four-cylinder engine of 140 h.p. with a gas generator working on wood fuel is being manufactured at Gorky (formerly Nizhni-Novgorod). Experiments in obtaining gas from peat, being made by the Diesel Research Institute in Moscow, have shown that with a slight alteration of the gas generator, a gas engine can be run on peat fuel.

Business Notes and News

New Heat-Treatment and Metal Degreasing Demonstration Centre

A heat-treatment and metal-degreasing demonstration centre is to be opened by Imperial Chemical Industries, Ltd., at the works of their subsidiary company, Lighting Trades, Ltd., at Earlsfield, London, S.W. 18, early in August.

Interest in modern salt-bath processes has grown so rapidly that a heat-treatment centre for the London area has become necessary, in addition to the one at Oldbury, Birmingham. The installation will include a representative range of gas-fired, oil-fired, and electric furnaces, and visitors will be welcomed by an expert metallurgist permanently in attendance. They will be able to see in operation the processes of case-hardening steels in cyanide and deep cementation in "Rapideep," and the heat-treatment of alloy steels in salt baths. Engineers will be specially interested in the demonstration of high-speed steel hardening by the "Carboneutral" process, which eliminates the bugbear of decarburisation.

Degreasing Plant.—A demonstration of I.C.I. metal degreasing plant will also be staged here to replace the one at Greenwich, as Earlsfield is more central. There will be working models of four gas-heated glants, the "Popular," "V2," "LV2" and No. 1 "3LO," in different sizes.

I.C.I. degreasing plant is designed for the removal of grease, waxes, oils, polishing compound, etc., from metal parts of all shapes and sizes. Apart from the standard range of nine plants which will be on show at Earlsfield, special models—gas, steam, or electrically heated—are designed for particular requirements.

Prince Chichibu Visits Metals Factory

His Imperial Highness Prince Chichibu of Japan recently visited the Kynoch Works of I.C.I. Metals, Ltd., at Witton, Birmingham. He was accompanied by Lord McGowan, Chairman of Imperial Chemical Industries, Ltd.; Mr. George Sale; Mr. H. O. Smith, a director of I.C.I.; Mr. A. J. G. Smout, who is in charge of I.C.I.'s operations in Birmingham; and Hon. H. W. McGowan.

At the Kynoch Works, where more than seven thousand people are employed, the Prince was shown some of the most up-to-date machinery in the British non-ferrous metal industry. The party visited the foundry and rolling mill, where charges weighing nearly half a ton are melted in electric furnaces, and the ingots passed to the rolls of a large reversing mill, which is probably the largest of its kind for rolling non-ferrous metals.

The rapidly increasing demand for rod in copper, brass, and the usual alloys has necessitated the building of a new rod mill, in equipment and size probably the most remarkable in the industry. Electric furnaces are again used for melting, but the moulds produce a round billet instead of the rectangular shape produced for strip manufacture.

Removal of Ban on Tin Prospecting

The removal of the ban on tin prospecting which has been in force in the Federated Malay States since 1931 means that Malayan tin mining companies can now acquire new ground and increase their reserves. It does not imply that the assessment of Malaya under the present control scheme will be increased.

The bulk of the present production is confined to a belt of about 150 miles long and 50 miles wide on the West coast, and of this about one-third of the total production comes from the Kinto Valley.

Much of Malay is unexplored as regards tin prospecting, and this new condition may mean the development of considerable reserves. Also, much of the ground previously worked by Chinese should offer definite possibilities if worked with modern dredging equipment.

The main source of supply for the British market is Bolivia, but Bolivia, once, if not now, the second most important producer of tin, has suffered consistent underproduction which has upset the tin market during the past year. World production during the past six months showing a shortage of 5,000 tons below apparent consumption.

It must be admitted that the demand for tin, since January, has been ahead of actual consumption, partly through increase of manufacturers' stocks, but the demand for tin should continue to increase, and greater contributions from Malaya will be more than welcome.

New Soviet Process for Production of Ferro-vanadium

A conference held under the auspices of the Central Administration of the Soviet Metallurgical Industry under the Commissariat of Heavy Industry, on June 28, discussed the question of developing the production of ferro-vanadium, used in the manufacture of quality steels, from titano-magnetite ores. It was stated at the Conference that there were large deposits of these ores at Pervouralsk, Kusinsk, Goroblagodatsk (in the Urals), Pudojgorsky (in Karelia), and elsewhere, which would form important bases of supply. Soviet experts have worked out a process of extracting ferro-vanadium from titano-magnetite ores, which has been thoroughly mastered by the Chusovaya Works in the Urals.

The process of direct recovery of titano-magnetite ores was held by the conference to be the most effective. This method has been tried out on a semi-industrial scale, and has been found considerably to simplify production, eliminating not only smelting in blast-furnaces, but also the processes of agglomeration and enriching. At the present time a small factory is being built in the Krivoy Rog Basin for the direct recovery of the ores. The experience gained in the work of this factory will serve as the basis for organising large-scale production of ferro-vanadium.

Further Reduction in Duty on Iron and Steel

Reduced rates of duty came into force on July 7, 1937, for the period ending March 31, 1938, reducing the duty on certain iron and steel goods. The total rate of duty chargeable on the following classes of iron and steel products is reduced to 12½% *ad valorem*: Ingots, blooms, billets and slabs; girders, beams, joists and pillars, angles, shapes and sections; bars and rods; plates and sheets; hoop and strip, but excluding hot-rolled strip more than 10 in. wide in coils exceeding 3 cwt., rails; forgings, drop forgings and rolls for mills, in the rough or machined; and castings, including rolls for rolling mills, stampings and pressings, in the rough or machined, of 7 lb. or more, but exclusive of domestic tanks, cisterns and gutters.

Any consignments of these goods, other than forgings and castings, imported with a quota certificate and certificate of origin, which are exempted from any additional duty under the provisions of the Additional Imports Duties (No. 3) Order of 1937, the total duty now chargeable will be 2½% *ad valorem*.

Beryllium may be Produced in Canada

A company has been formed to develop a block of approximately 3,000 acres in Renfrew County, Eastern Ontario, in which a quantity of beryl ore has been recovered and binned from a small cut about 8 ft. wide, 8 ft. deep, and 50 ft. in length. The stripping of further overburden is stated to have disclosed much larger bodies of ore, which are now being mined.

The name of the company is Canadian Beryllium Mines and Alloys, Ltd., and it is capitalised at 3,000,000 shares, $1 par, of which 1,000,000 have been issued for the properties and are pooled. An offering of 600,000 Treasury shares is being made for development purposes and working capital.

The Iron and Steel Institute

The Council of the Iron and Steel Institute announce that Monsieur Léon Guillet, Director of the Ecole Centrale des Arts et Manufactures, and Professor at the Conservatoire des Arts et Metiers, Paris, has been nominated an honorary Vice-President of the Institute, and that Dr. C. A. Edwards, F.R.S., Principal of University College, Swansea, has been elected a member of Council.

More Blast-Furnaces Rekindled

The number of blast-furnaces operating in the North-East coast area is now 34, as compared with 29 last year. Production of basic and hæmatite iron will be increased by the restarting of two blast-furnaces on Teeside, the South Durham Steel and Iron Co., Ltd. rekindling two furnaces at Seaton Carew.

Messrs. Dorman, Long and Co., Ltd., have rekindled a blast-furnace at their Cleveland works, for the production of hæmatite iron.

Ore supplies are maintained on a basis that is described as "fairly satisfactory," but customers in the foundry trade are not receiving adequate supplies of pig-iron. The prices of both hæmatite and foundry iron remain unchanged.

Effect of Welding on Design

At the recent Institute of Welding lecture, Mr. Jas. F. Lincoln, E.E., U.S.A., said that welding was going to have a remarkable effect on the design of machines, a change that is not yet fully realised. He used a series of slides to show the greater value of the shielded arc over the unshielded arc in all types of electric welding, especially where corrosion must be considered.

Pictures were shown to illustrate the greater strength of welded construction, as compared with rivetted units, instances including cranes, ships, railway coaches, pipes, motor-cars, boilers and houses.

Mr. Lincoln stated that the greatest changes in manufacturers' designs would be made by the use of high-speed steel, alloy steel and arc welding. He has offered the total sum of £40,000 in different prizes in an engineering competition for the best papers on welding. The best paper on welding would gain a prize of £2,300, and there were 445 other prizes. Papers have to be presented by June 1, 1938.

Inquiries regarding this competition should be addressed to the secretary, the James F. Lincoln Arc Welding Foundation, P.O. Box 5728, Cleveland, Ohio. The rules of the Foundation state that the object of the award is to encourage architects, engineers, designers and production managers to study products which are now partially welded, so that electric welding may be applied more extensively, the primary object being to encourage study of products and structure built by some other method, so that electric welding may be used in construction. The machine, structure, building, manufactured or fabricated product may be designed, either in whole or part, for the use of arc welding.

Miniature Ball Bearing for Precision Instruments

There are countless small mechanisms which at present use plain or jewel bearings in their construction, these including small electric motors, recorders, meters, clockwork, speed indicators, tachometers, pressure gauges, scientific instruments, weighing mechanisms, etc. If very small ball-bearings were available at reasonable prices they could be employed with great advantage in all these products.

A well-known Swiss manufacturer of watch parts undertook the development and manufacture on a commercial scale of ball bearings so small that they could be substituted for ruby, sapphire and plain bearings in all forms of clockwork, motors, delicate machines and sensitive measuring instruments. This ideal is now a practical commercial reality, miniature ball bearings being produced in quantity to standards of extreme precision, although the overall size of a complete bearing, including race, ranges from 1·5 mm. upwards. A further important advance will shortly be realised when complete bearings of only 1 mm. overall size will become available.

The advent of these miniature ball bearings will not only add to the efficiency of existing instruments, but will render possible the design of ultra sensitive meters, etc., not hitherto available to industry.

Tests have been made to find out the reduction in friction resulting from the use of miniature ball bearings, instead of jewels and pivots. The mean damping time for rotational motion in identical conditions was eight times longer than for plain, and 20 times longer than for tapered pivots. An oscillation test gave similar results. These ball bearings have an extremely low co-efficient of friction, and approximately the same force is required for starting as when running.

These miniature ball bearings are patented in all principal countries, and are the invention and production of Roulements a Billes Miniatures S.A., of Switzerland. Information regarding them can be obtained from International Technical Developments, Ltd., Thames House, S.W. 1, who are the exclusive British agents.

Large Steel Stampings

The Ford V-8 saloon body includes the largest steel stamping ever used in Ford production, this extending from the top of the windscreen to below the rear window and from side to side down the side panels and doors. The stamping is electrically welded with the body structure, this including the internal panels and the steel floor, and forming a single unit of great strength. No woodwork is now included in the body skeleton structure.

Catalogues and Other Publications

The current issue of *Monel Notes*, No. 3, introduces Monel plywood, which can be supplied covered on one or both sides, in the latter case the edges can be sealed. It also describes the use of Monel for Kingwood disc valves, notes on the welding of cast iron, with Monel electrodes to provide a welded join which will be amenable to machining.

The standard forms of Monel are listed, together with the types and dimensions of the various forms produced, and interesting information of specific applications of Monel for either acid or alkali corrosion resistance purposes is given.

The second production of "Aluminium Welding," a new series of technical information booklets issued by the British Oxygen Co., Ltd., describes the composition and mechanical properties of "Alda" aluminium welding rods and outlines where and how these rods may be applied; the booklet naturally being concerned with the welding of aluminium by oxy-acetylene blowpipe flame. These welding rods are of pure aluminium, 5% silicon aluminium, 10% silicon aluminium, and 5% copper aluminium, the hardest deposit being obtained from the latter.

Useful information on the application of aluminium and aluminium alloy welding is included. The company supply on request a patent binder with Napierien rod fastening, measuring 10½ in. × 7½ in. This can be obtained from any of their various branches or from head office at Thames House, Millbank, Westminster, S.W. 1.

The Aluminium Union, Ltd., have produced a list of selected aluminium alloys, comprising those alloys in most general use stocked by this company. Mechanical, physical, chemical, and foundry properties and specifications are tabulated, and there are two pages devoted to remarks concerning the types and uses of these fourteen alloys.

Those alloys which meet Air Ministry, Admiralty, and other special specifications are indicated by the appropriate specification number. The alloys listed are: 123, 125 (D.T.D. 272, D.T.D. 276), 160 (L. 33), 161 (D.T.D. 240, D.T.D. 245), 162 (Lo. Ex.), 218 ('Y', 2 L. 24, L. 35), 224, 232, (4 L. 11), 250, 260 (3 L. 8, 362), 305, 320, 322, 465 (3 L. 5). Copies can be obtained from the Aluminium Union, Ltd., Bush House, London, W.ff. 2.

An eight-page brochure produced by Head, Wrightson and Co., Ltd., gives complete and useful data on their heat-resisting steels, marketed under the brand names of "Shadrach," "Meshach," and "Abednego." It is claimed for these three grades of steel that their use results in a saving in cost of material or in maintenance labour, or in both combined.

"Abednego" steel is an austenitic chromium-nickel alloy of high strength and ductility at elevated temperatures, and well adapted to withstand oxidation, erosion, and corrosion of combustion products at temperatures up to 1,150° C. It may be used in atmospheres of moderate sulphur content. The other two steels are high chromium nickel-free alloys, particularly resistant to scaling and the influence of sulphur and its gaseous compounds at high temperatures. The maximum temperatures specified for their use are: "Shadrach," 1,050° C.; "Meshach," 1,150° C. These steels do not harden by heat-treatment, have good abrasion-resisting properties, and are rather more brittle than "Abednego" steel.

We have received from John Rolland and Co., Ltd., Abbey House, 2, Victoria Street, London, S.W. 1, a 16-page catalogue of rolling mills manufactured by Fried, Krupp Grusonwerk A.G. of Magdeburg. Well produced and illustrated, this catalogue is tri-lingual (French, German, and English), and shows a number of rolling mills and auxiliary machines installed during 1936. Illustrations include: Bloom-discharging device, 3-high stand for rolls 33½ in. to 35½ in. diameter by 87 in. barrel length; 3-high blooming mill, with rolls 29½ in. diameter and 85 in. long, with combined electric screw-down and balancing gear and top roll; 3-high copper wire rod mill, with 15 in. diameter rolls; vertical edging stand; mechanical cooling bed; rotary shears; crop and other shears; automatic tables; several 3-high plate mills; 3-high sheet mill; dressing stand; 2-high and 3-high mills for non-ferrous metals; continuous billet mills; motor rollers shown disassembled; 4-high and cluster mills; other cold-rolling mills and various rolls.

Society of Chemical Industry

The Annual General Meeting

THE question of what a man going into business ought to study during his last year or so at school or at the University, was raised by Lord Leverhulme in his presidential address at the recent annual meeting of the Society of Chemical Industry, he emphasised that whether that business career lies on the technical side of industry or not, a scientific training is valuable because scientific method and habit of thought have an application far beyond the confines of technical research and technical processes.

In estimating the service of science to industry, Lord Leverhulme said, we must take account nor only of discoveries in the realm of natural sciences, chemistry conspicuously, but also of the service which scientific method the handmaid of all sciences, renders by enabling industry to manufacture and distribute more goods, with less waste, for the greater benefit of the producer and the consumer. We are now witnessing the synthetic production of an increasing number of raw materials, indicative of an economic resolution, the proximity and scope of which are not yet sufficiently appreciated, and that the time is near when we shall be largely independent of the accident of geographical or climatic environment, relying to a great extent upon the chemist as the universal provider of substitutes. The elimination of waste leading to conservation of resources reflects great credit upon the chemist, and he will receive the greatest recognition from a world wherein the gradual exhaustion of nature's resources is being accelerated by the increasing demands made upon those resources.

In this conservation of resources the chemist develops substitutes and releases more costly materials for use in other processes, and in developing those substitutes he uses materials which may have been of no previous economic value.

Trends in Chemical Science

A survey of the trends in chemical science during the past sixty years was made by Professor G. G. Henderson, referring to the modern theory of stereoisomerism outlined by Le Bel and Van't Hoff in 1874, the theory of ionisation advanced by Arrhenius in 1887, the separation of the "rare gases" from the atmosphere, the discovery of radioactivity and X-rays leading to the modern theory of the atom. He referred also to the possibility of "producing experimentally new elements which, so far as is known, do not occur in nature," of the addition of X-rays, ultraviolet and infra-red radiation, and of the delicate weapon of micro-analysis to the analyst's equipment.

Prof. Henderson also spoke of the evident fact that there are few of our productive industries which are not to some extent at least dependent upon the work of the chemist and of the steadily increasing demand for the services of chemists both by chemical industries and by industries which are not, strictly speaking, chemical, and of the marked appreciation of chemical research.

The speaker pointed out that the last few decades have witnessed the production of new classes of valuable dyestuffs, synthetic drugs, many different types of plastic, rubber substitutes, rayon, and of numerous valuable alloys. He concluded with an appeal for unity among chemical scientists, stating that the future prosperity of our country is largely dependent on the support given to the progress of science.

Special Alloys of Cast Iron

The advantages and compositions of special alloys of cast iron were discussed by Dr. A. B. Everest, with special emphasis on those based upon the addition of nickel, pointing out that such alloys compared with the traditional cast iron could give mechanical strength twice or three times greater, a degree of hardness not possessed by any other cast metal, and up to 500 times the resistance to certain acids.

He contrasted the cheapness, ease of casting and machining of cast iron with its possibility of porosity and open grain and the consequent reduction in wearability and resistance to corrosion, and explained that attention had been mainly directed, in developing special cast irons, to minimisation of segregation and modification of the matrix.

Dr. Everest outlined the qualities and limitations of various alloying metals, showing how vanadium and titanium can only be used in small quantities and for refining and deoxidising the metal, that tungsten has been little used in cast iron and its influence not yet fully understood, that copper also can only be used in small proportions, owing to its limited solubility in iron except when in the presence of certain other elements, such as nickel, which serve to carry it in solution. He referred to the ability to add chromium and manganese in much greater proportion, but pointed out that the affinity between these elements and the carbon in the iron resulted in the formation of massive carbides which make the final castings hard and difficult to machine, but that alloys with high proportions of chromium have a high degree of heat resistance. Molybdenum, also, tends to form carbides and is generally used in small proportions.

Nickel was quoted as the most useful of the alloy additions, as it can be added in all proportions, providing a series of metals with a diversity of properties, and further enhanced by the fact that it is not lost by oxidation on remelting. Additions of nickel up to 2% have proved useful in controlling the grain size and physical properties of good quality cast iron; additions above 2% harden the matrix; at about 5% of nickel the influence of the nickel in lowering the critical points at which constitutional change takes place in the metal makes the alloys air- or self-hardening, and the matrix of the iron is in the hard martensitic form, so that such irons are difficult to machine, but have good abrasion resistance. Further additions of nickel result in a series of irons of gradually decreasing hardness, due to the gradual replacement of the martensitic matrix by austenite, until at 16–20% of nickel the castings are soft and easily machined. The matrix change is complete at about 20% of nickel. These austenitic cast irons are corrosion and heat resistant, with good resistance to abrasion, and this series of alloy cast irons has proved of considerable interest to chemical engineers. Their strength of 22–25 tons per square inch is quite usual in large castings.

"Ni-hard" (4½% nickel, 1½% chromium) was referred to as the hardest known cast metal, whilst cast iron containing 7–8% of nickel and 2–3% of chromium had been proved to possess many times the life of special steels for high-speed pumping.

The cheapest austenitic iron is "Nomag" (10–12% nickel, 5–6% manganese), but had inferior corrosion resistance; "Ni-Resist" (14% nickel, 6% copper, 2% chromium) was of special interest to chemical engineers owing to its resistance to alkaline solutions, concentrations of caustic, and to weak acids. The many other properties of "Ni-resist" are described elsewhere in this issue. Finally, there is "Nicrosilal," of 18% nickel and 4–6% silicon, which combines good corrosion resistance with superior heat and oxidation resistance.

The output of the Whitehead Iron and Steel Co., Ltd. expanded from 206,000 tons to 240,000 tons during the past year, and the cold-rolling department has given very satisfactory results. It will be recalled that an American four-high reversing mill was put into commission during the early part of last year.

MARKET PRICES

ALUMINIUM.

		£	s.	d.
98/99% Purity		£100	0	0

ANTIMONY.

		£	s.	d.
English		£83	10	0
Chinese		69	0	0
Crude		35	10	0

BRASS.

		£	s.	d.
Solid Drawn Tubes	lb.	0	1	0¼
Brazed Tubes	,,	0	1	2¼
Rods Drawn	,,	0	0	11¼
Wire	,,	0	0	9¾
*Extruded Brass Bars	,,	0	0	7

COPPER.

		£	s.	d.
Standard Cash		£58	0	0
Electrolytic		63	10	0
Best Selected		65	0	0
Tough		64	10	0
Sheets		95	0	0
Wire Bars		65	0	0
Ingot Bars		65	0	0
Solid Drawn Tubes	lb.	0	1	2¼
Brazed Tubes	,,	0	1	2¼

FERRO ALLOYS.

		£	s.	d.
‡Tungsten Metal Powder	lb.	£0	5	1½
‡Ferro Tungsten	,,	0	5	0
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2–4% Carbon, scale 12/- per unit	ton	35	10	0
NOMINAL: 4–6% Carbon, scale 8/- per unit	,,	24	10	0
NOMINAL: 6–8% Carbon, scale 7/6 per unit	,,	24	0	0
NOMINAL: 8–10% Carbon, scale 7/6 per unit	,,	24	0	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	,,	37	0	0
Guar. max. 1% Carbon. scale 13/- per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/- per unit	,,	49	0	0
‡Manganese Metal 97–98% Mn	lb.	0	1	3
‡Metallic Chromium	,,	0	2	5
§Ferro-Vanadium 25–50%	,,	0	12	8
§Spiegel, 18–20%	ton	8	5	0
Ferro Silicon—				
Basis 10%, scale 3/- per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	,,	14	0	0
45/50% basis 45%, scale 5/- per unit	,,	12	0	0
70/80% basis 75%, scale 7/- per unit	,,	17	0	0
90/95% basis 90%, scale 10/- per unit	,,	30	0	0
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	15	15	0
§Ferro - Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	5

FUELS.

		£	s.	d.
Foundry Coke—				
S. Wales	—	2	2	6
Scotland	—	1	17	6
Durham	—	1	17	0
Furnace Coke—				
Scotland	—	1	15	0
S. Wales	—	1	16	0
Durham	—	1	15	0

GUN METAL.

		£	s.	d.
*Admiralty Gunmetal Ingots (88 : 10 : 2)		£85	0	0
*Commercial Ingots		69	5	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	1	1
*Cored Bars	,,	0	1	3

MANUFACTURED IRON.

	£	s.	d.
Scotland—			
Crown Bars,	£11	17	0
N.E. Coast—			
Rivets	11	15	0
Best Bars	12	10	0
Common Bars	10	15	0
Lancashire—			
Crown Bars	11	17	6
Hoops	12	15	0
Midlands—			
Crown Bars	11	17	6
Marked Bars	14	7	6
Unmarked Bars	—		
Nut and Bolt Iron	10	15	0
Gas Strip	12	15	0
S. Yorks.—			
Best Bars	11	17	0
Hoops	12	15	0

PHOSPHOR BRONZE.

		£	s.	d.
*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	1	1
*Cored Bars	,,	0	1	3
†Strip	,,	0	1	1¼
†Sheet to 10 W.G.	,,	0	1	1¾
†Wire	,,	0	1	3¼
†Rods	,,	0	1	4
†Tubes	,,	0	1	6½
†Castings	,,	0	1	3½

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

	£	s.	d.
Scotland—			
Hæmatite M/Nos.	£6	3	0
Foundry No. 1	5	15	6
,, No. 3	5	13	0
N.E. Coast—			
Hæmatite No. 1	6	3	0
Foundry No. 1	4	3	6
,, No. 3	4	1	0
,, No. 4	4	0	0
Silicon Iron	—		
Forge	4	0	0
Midlands—			
N. Staffs. Forge No. 4	4	3	0
,, Foundry No. 3	4	6	0
Northants—			
Foundry No. 1	4	6	6
Forge No. 4	4	0	6
Foundry No. 3	4	3	6
Derbyshire Forge	4	3	0
,, Foundry No. 1	4	9	0
,, Foundry No. 3	4	6	0
West Coast Hæmatite	6	8	6
East ,, ,,	—		

SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0·015, of phosphorus 0·025.	
Per English ton	Kr.180
Billets, single welded, over 0·45 Carbon.	
Per metric ton	Kr.315-385
Per English ton	£16 5 0/£19 17 6
Wire Rods, over 0·45 Carbon.	
Per metric ton	Kr.365-415
Per English ton	£18 17 6/£21 15 0
Rolled Martin Iron, basis price.	
Per metric ton	Kr.315-330
Per English ton	£16 5 0/£17 0 0
Rolled charcoal iron, finished bars, basis price.	
Per metric ton	Kr.360
Per English ton	£18 12 6

f.o.b. Gothenburg.

SCRAP METAL.

	£	s.	d.
Copper, Clean	£48	0	0
,, Braziery	43	0	0
,, Wire	—		
Brass	30	0	0
Gun Metal	45	10	0
Zinc	14	15	0
Aluminium Cuttings	74	0	0
Lead	19	10	0
Heavy Steel—			
S. Wales	3	10	0
Scotland	3	6	0
Cleveland	3	7	0
Cast Iron—			
Midlands	3	5	0
S. Wales	3	10	0
Cleveland	4	2	6
Steel Turnings—			
Cleveland	2	12	6
Midlands	2	5	0
Cast Iron Borings—			
Cleveland	—		
Scotland	2	2	6

SPELTER.

	£	s.	d.
G.O.B. Official	—		
Hard	£20	0	0
English	24	0	0
India	20	10	0
Re-melted	20	10	0

STEEL.

	£	s.	d.
Ship, Bridge, and Tank Plates.			
Scotland	£11	10	0
North-East Coast	11	10	0
Midlands	11	10	0
Boiler Plates (Land) Scotland	12	0	0
,, ,, (Marine) ,,	—		
,, ,, (Land), N.E.Coast	12	0	0
,, ,, (Marine) ,,	—		
Angles, Scotland	11	0	6
,, North-East Coast	11	0	6
,, Midlands	11	0	6
Joists	11	6	0
Heavy Rails	10	2	6
Fishplates	14	2	6
Light Rails	10	7	6
Sheffield—			
Siemens Acid Billets	11	15	0
Hard Basic .. £6 17 6 to	10	2	6
Medium Basic, £6 12 6 and	10	0	0
Soft Basic	8	15	0
Hoops	11	15	0
Manchester			
Hoops	11	5	0
Scotland, Sheets 24 B.G.	15	15	0

HIGH-SPEED TOOL STEEL.

		£	s.	d.
Finished Bars 14% Tungsten	lb.	£0	2	7
Finished Bars 18% Tungsten	,,	0	3	6
Extras :				
Round and Squares, ½ in. to ¼ in.	,,	0	0	3
Under ¼ in. to 3/16 in.	,,	0	1	0
Round and Squares, 3 in.	,,	0	0	4
Flats under 1 in. × ⅜ in.	,,	0	0	3
,, ,, ½ in. × ¼ in.	,,	0	1	0

TIN.

	£	s.	d.
Standard Cash	£266	10	0
English	266	15	0
Australian	—		
Eastern	266	0	0
Tin Plates I.C. 20 × 14 box	1	5	6

ZINC.

	£	s.	d.
English Sheets	£36	0	0
Rods	30	0	0
Battery Plates	—		
Boiler Plates	—		

LEAD.

	£	s.	d.
Soft Foreign	£25	2	6
English	27	0	0

* McKechnie Brothers, Ltd., July 11. † C. Clifford & Son, Ltd., July 11. ‡ Murex Limited, July 11.
Subject to Market fluctuations. Buyers are advised to send inquiries for current prices when about to place order.
§ Prices ex warehouse, July 11.

FILE THIS IN YOUR CABINET

You will then be able to refer to contents of previous issues easily.

METALLURGIA. Contents. For JULY, 1937.

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Electromagnets, Ltd., 48, High Street, Erdington, Birmingham.
Motors (Electric)
Metropolitan-Vickers, Ltd., Trafford Park, Manchester.
Naval Brass Ingots
McKechnie Bros. Ltd., Rotton Park St., Birmingham.
Non-Ferrous Alloys
Clifford, Chas. and Son, Ltd., Birmingham
Manganese Bronze and Brass Co. Ltd., Handford Works, Ipswich
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
High Duty Alloys, Ltd., Trading Estate, Slough.
I.C.I. Metals Ltd., Kynoch Works, Witton, Birmingham, 6.
Non-Ferrous Metals
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I.C.I. Metals Ltd., Kynoch Works, Witton, Birmingham, 6
McKechnie Bros. Ltd., Rotton Park St., Birmingham.
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Dunford & Elliott, Ltd., Sheffield.
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Sanderson Bros. and Newbould, Ltd., Sheffield
United Steel Companies, Ltd., Sheffield.
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Steel Tubes aud Sections
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Wellman Smith Owen Engineering Corporation, Ltd., Victoria Station House, London, S.W. 1.
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Ether, Ltd., Tyburn Road, Birmingham.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
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Vitreosil Combustion Tube
Thermal Syndicate, Ltd., Wallsend-on-Tyne.

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All classes of Steel to comply with War Office, Admiralty, Air Ministry and British Standard Specifications; selected Steels to B.S.S. 256 and 351.
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